

Control ENGINEERING

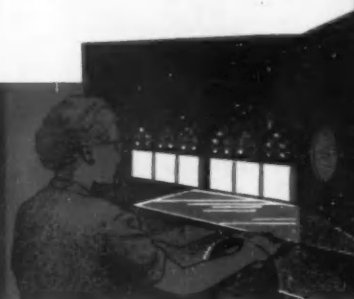
INSTRUMENTATION AND CONTROL SYSTEMS

A McGraw-Hill Publication

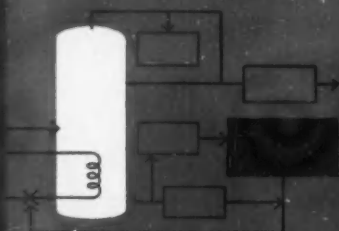
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OCTOBER 1960

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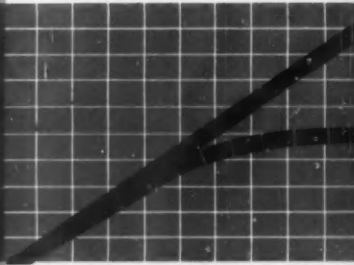
Mechanizing
the Adaptive Principle



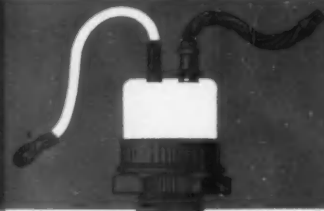
Emergency Air Capacity



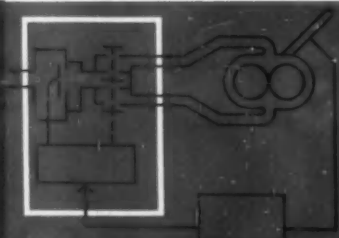
Compensating Dc Motors
for Fast Response



PNPN Diodes and Triodes



Stabilizing On-Off
Pneumatic Controls



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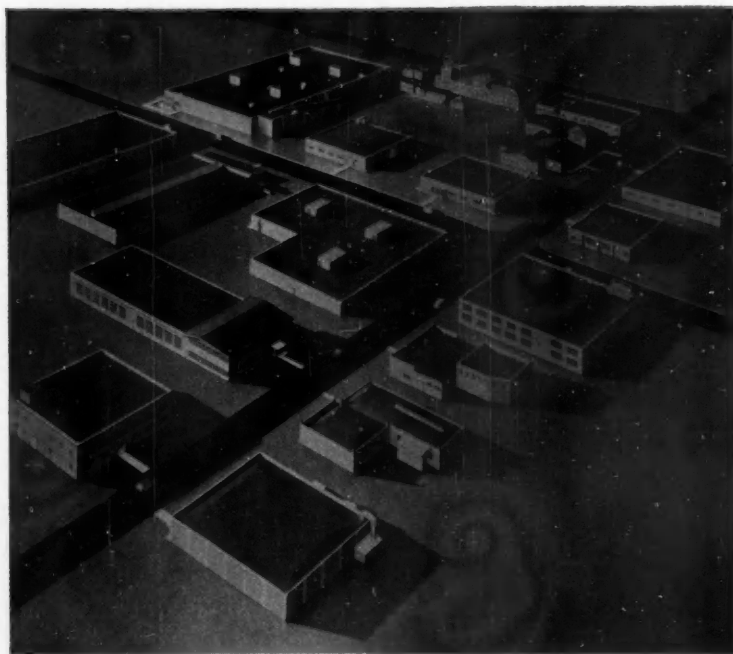
Shown below is a composite view of Librascope's facilities where a variety of computer systems are currently in different stages of design and production. Some are strategically involved with national defense...others deal with business and industrial process control. Each is uniquely designed to answer a particular need. The success of these systems illustrates the value of Librascope's engineering philosophy: A decentralized organization of specialized project teams responsible for assignments from concept to delivery...and backed up by excellent research, service, and facilities. For your computer requirements, call on the company of diversification in computer technology is unsurpassed. Division, General Precision, Inc., 808 Western Avenue, For career opportunities write to John Schmidt, Engineering

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computers that pace man's expanding mind



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greater resolution at decade
voltage points where other 4-digit
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one full digit of resolution.*

The KIN TEL Model 501 4-digit, over-ranging digital voltmeter measures DC from ± 0.0001 to ± 1000.0 volts with $0.01\% \pm 1$ digit (of reading) accuracy. An extra fifth digit in the left decade indicates "0" or "1" to provide ten times greater resolution at decade (1, 10, 100) voltage points than standard 4-digit voltmeters. Ranging and polarity indication are entirely automatic. The measured voltage, decimal point and polarity symbol are displayed on an in-line readout in a single plane—no superimposed outlines of "off" digits.

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The 501 is one of a complete line of KIN TEL digital instruments. Others include AC converters, AC and DC preamplifiers, ratiometers, and multi-channel input scanners.

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Display... Six decades display 5 digits (Left digit "0" or "1" only), decimal point, polarity symbol. Ranging and polarity indication are automatic. Projection system readout employs bayonet-base lamps with 3000-hour minimum life rating. Readout contains no electronic circuitry and can be remotely mounted.

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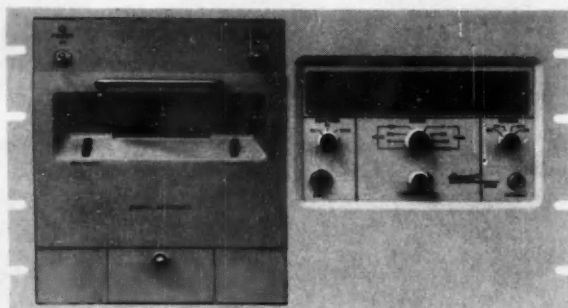
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KIN TEL manufactures electronic instruments for measurement and control, and closed circuit TV. Representatives in all major cities. Write for detailed literature or demonstration.

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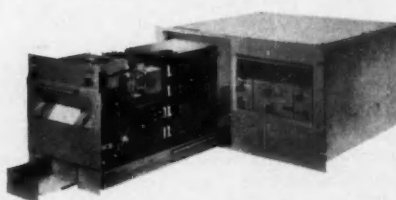
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Control ENGINEERING

OCTOBER 1960

VOL. 7 NO. 10

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

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VOL. 7 NO. 10

Published for engineers and technical management men responsible for the design, application, and test of automatic control systems

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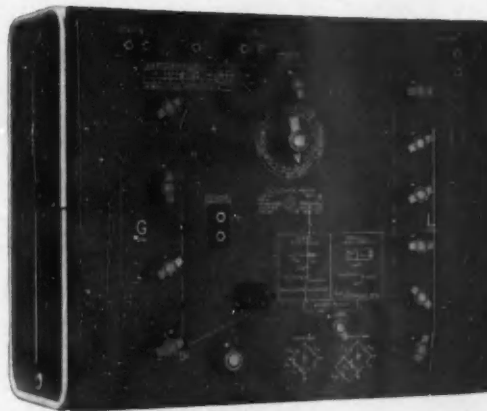


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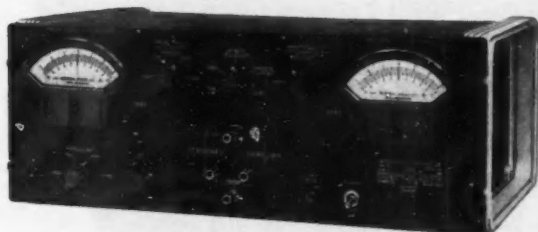
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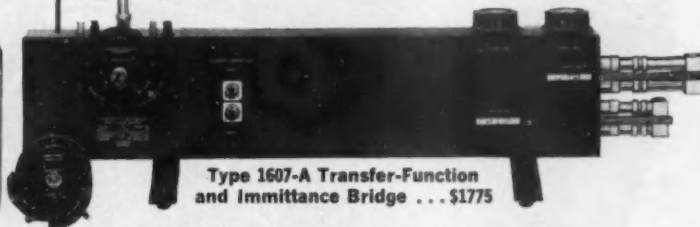
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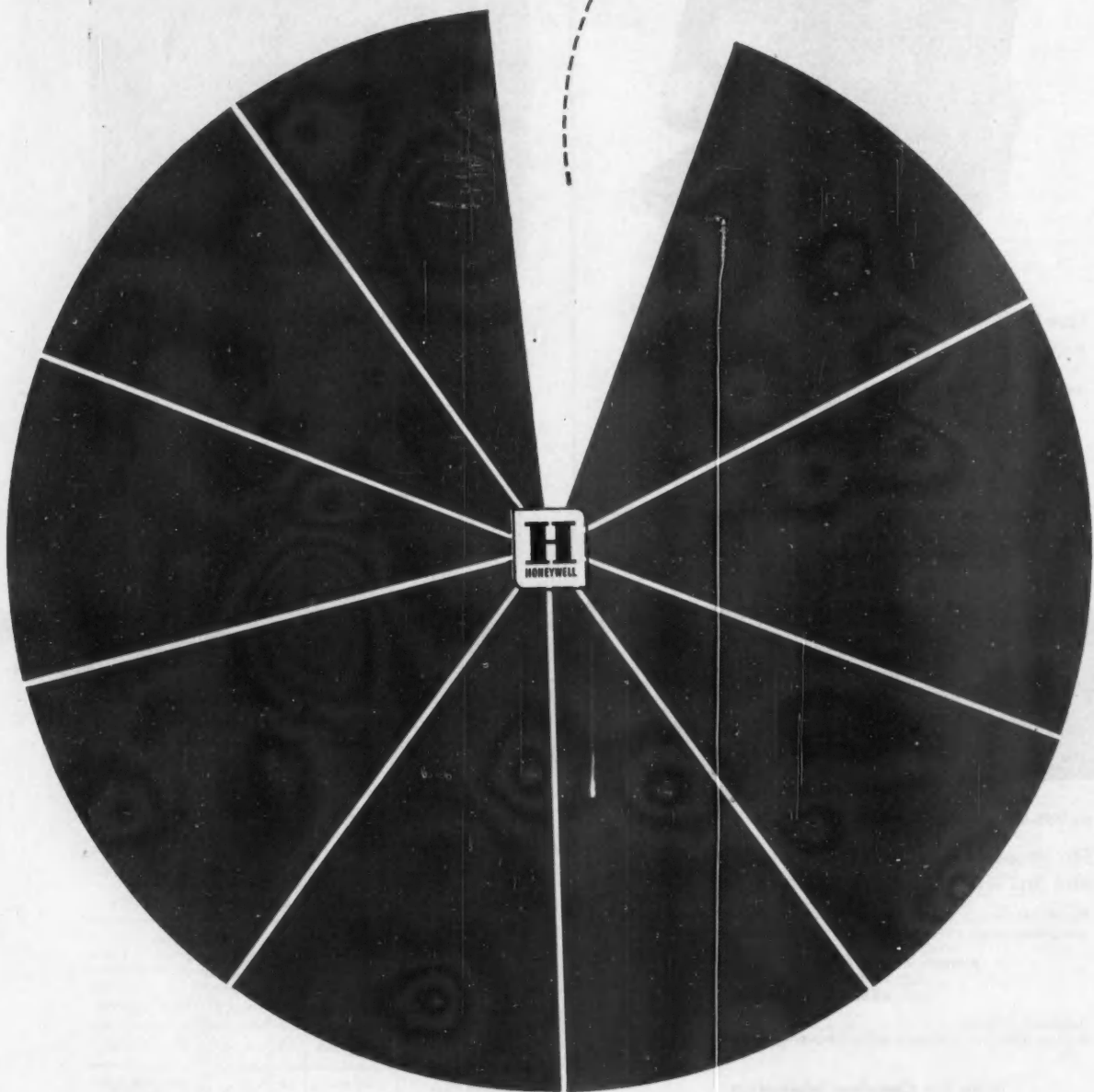
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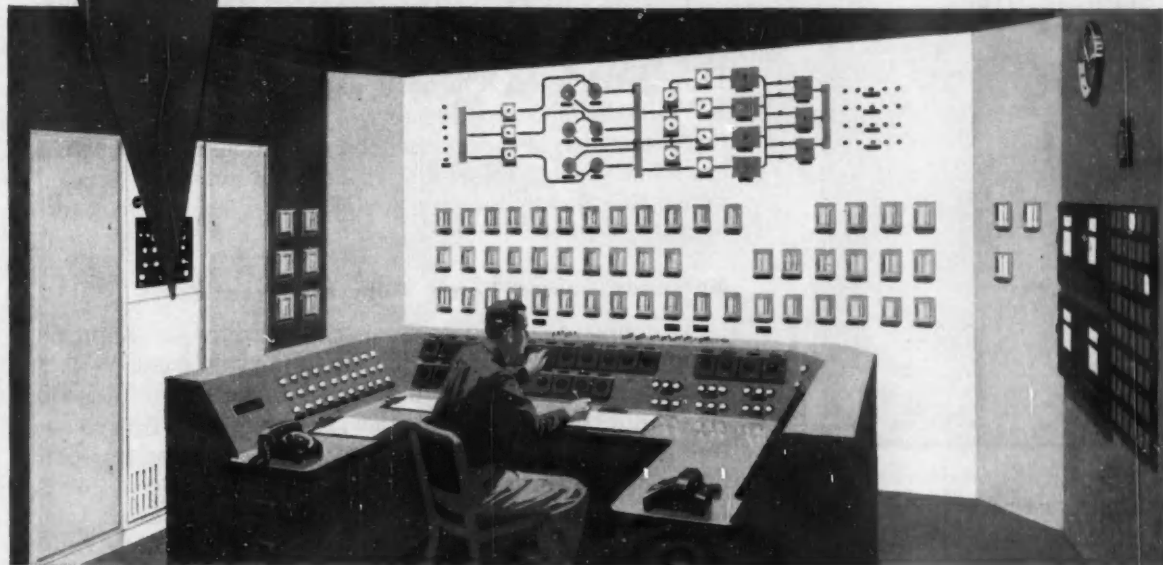
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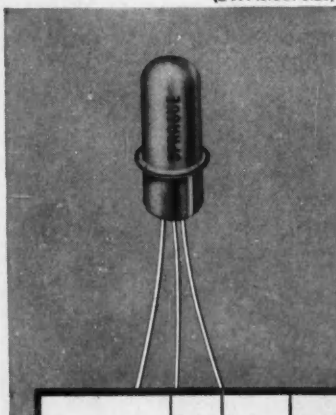


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SHOPTALK

Major case study of computing-control

Next month's CONTROL ENGINEERING will include a special 12-page report featuring the control aspects of the single largest and most complex computer controlled chemical process operating today—Monsanto's ammonia unit at the Barton Plant in Luling, La. Operating under full-time control of an RW-300 digital computing-control system for several months, this process has already given good indications of meeting the economic payout goal set down for it. Don't miss this detailed article that reveals the step-by-step factors leading to a successful system.

Kompass comes home from the West

As Shoptalk goes to press, Assistant Editor Ed Kompass returns to New York after a month on the west coast. With a healthy tan and a touch of the normal west coast enthusiasm, Ed is bubbling over with the new, the bigger, the better control projects being tackled in Seattle, San Francisco, San Diego, Los Angeles, Phoenix, and points in-between. Starting with the WESCON report on page 38 of this issue, C&E readers will benefit from Ed's impressions and article commitments as the months go by.

What makes a control engineer?

We've encountered control engineers who were physicists, chemical process engineers, master mechanics, and tool engineers, but probably the strangest group we have ever run into is the seven men who developed the automatic operant behavior laboratory at Schering Drug Co. (see "Computers Unfold the Secrets of Human Behavior", page 120). While garnering the facts for this story, Associate Editor Lew Young found that five of these men were educated as psychologists, chemists, and biologists and later taught themselves electronics, instrumentation, and computer techniques so that they could gather and process the information necessary to study operant behavior. Incidentally, you'll find this article interesting not only because of the unusual accomplishments of the personnel, but also because of the implications of their work.

Reader feedback requested

Since CONTROL ENGINEERING was started six years ago, the editors have depended on feedback from the readers to keep the magazine on course and stable. Anytime you have a gripe, a new idea, opinions about published material, article suggestions, or a need for information about specific portions of the field, let us hear from you. Our job is to move the control field ahead, and comments from the readers really help.



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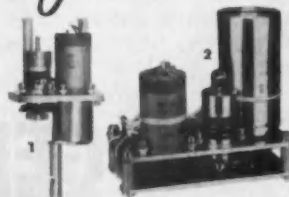
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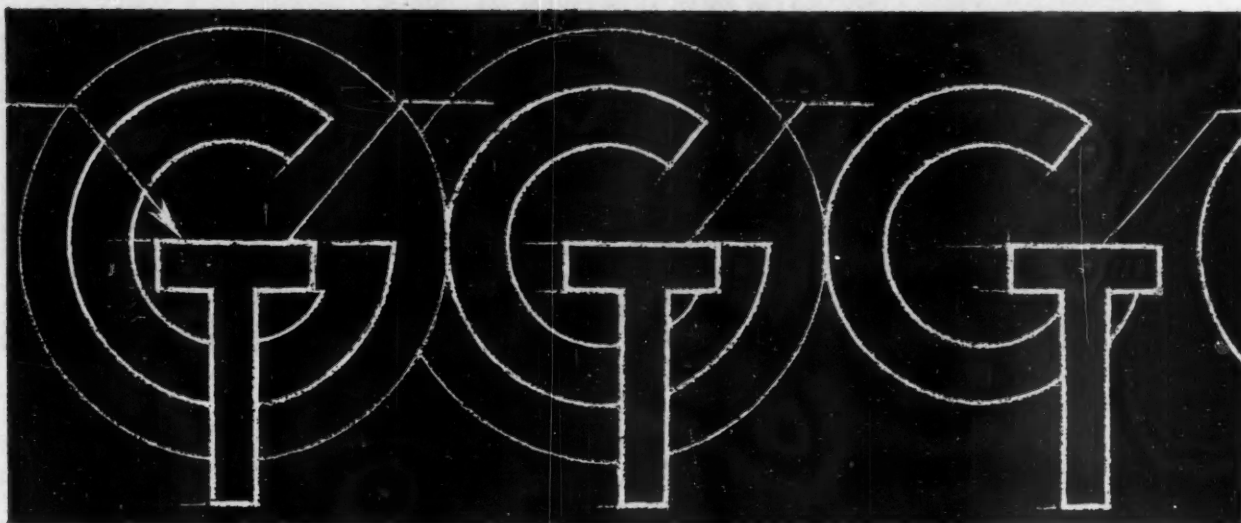


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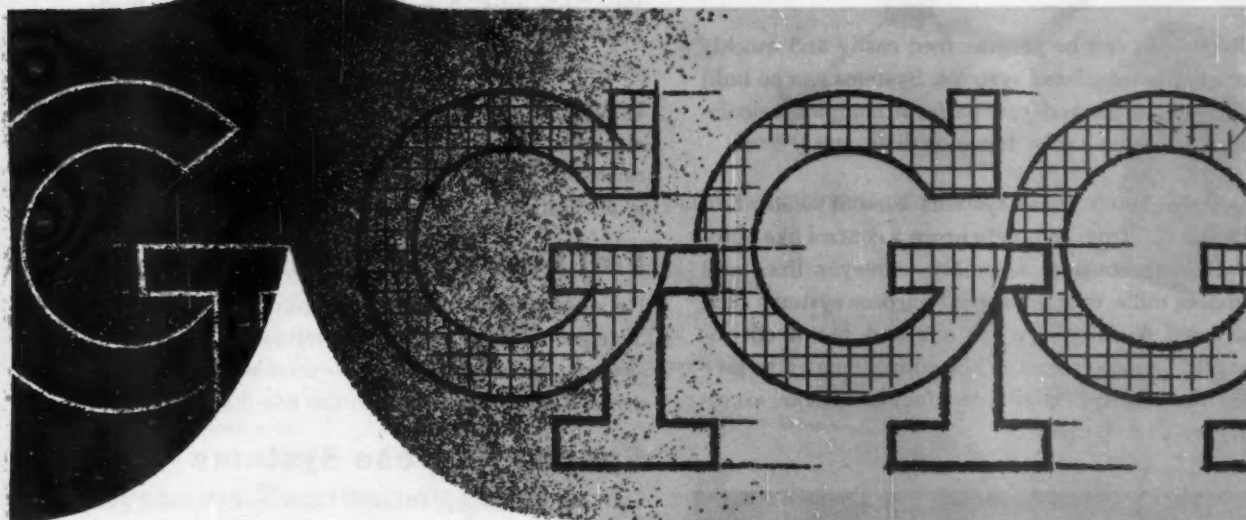


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RELIANCE

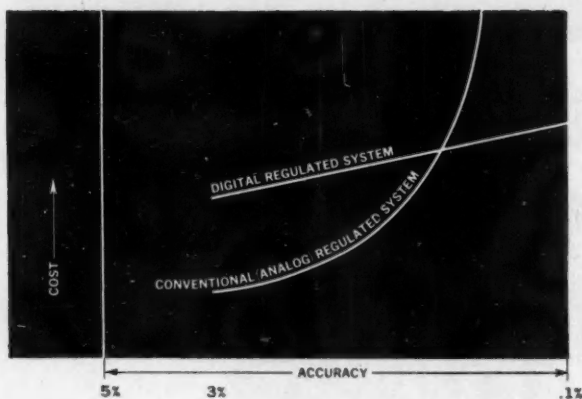
DIGITAL REGULATED

...accurate...economical...and

When accuracy requirements are greater than 1/10 of 1%, and where drift can cause a problem, these Reliance digital systems offer you an excellent answer.

Commands can be programmed easily and quickly into digital regulated systems. Systems can be built with memories and can perform complex calculations . . . from cards, tapes or dials.

Reliance builds these systems custom tailored to the job . . . from complete process control like automatic warehousing, assembly conveyor lines and tandem mills, to small special purpose systems such as press feeders, pipe cut-offs and board cut-to-length. These systems can be simple enough to give you the benefit of digital techniques without excessive cost or complexity.



DIGITAL SYSTEMS OFFER ECONOMIC ADVANTAGES

No-Drift Accuracy

Where analog-regulated systems rely on magnitude and polarity of feed-back signals compared with a reference, variations in reference will cause drift. Digital systems, however, receive "discrete pulses"; magnitude of pulse is not important.

Limitation on accuracy is usually mechanical; the electrical system is capable of .001% or better. Because of "discrete pulses", drift is eliminated. There is no cumulative error.

Full System Responsibility

Reliance gives you more than just digital regulation. You get an integrated, comprehensive, engineered system, including motors, variable speed (V*S) drive, digital regulator and the command control.

Special Purpose Systems

Starting with standard industrial components, Reliance designs a complete system — for rugged, maintenance-free, in-plant operation. Controls, in standard enclosures, are available for installation at the machine site.

Digital Press Feeder Control

This system is a prime example of precise control. Pre-set sheet lengths are programmed into the digital regulator with selector switches. The system permits the press to operate at maximum speed while compensating for sheet length and speed. Reliance V*S Drives supply the motive power . . . for increased production efficiency.

DRIVE SYSTEMS

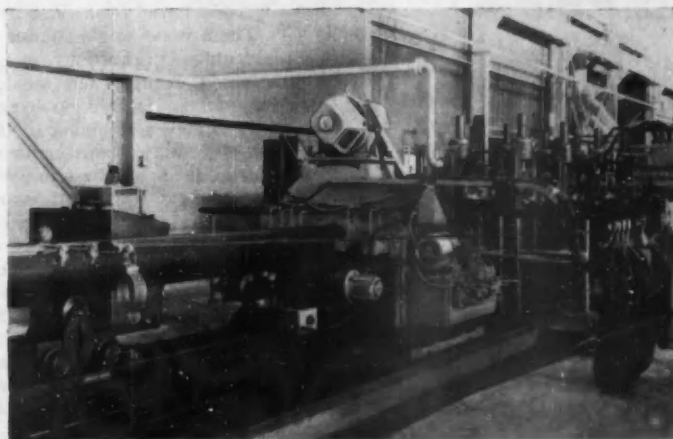
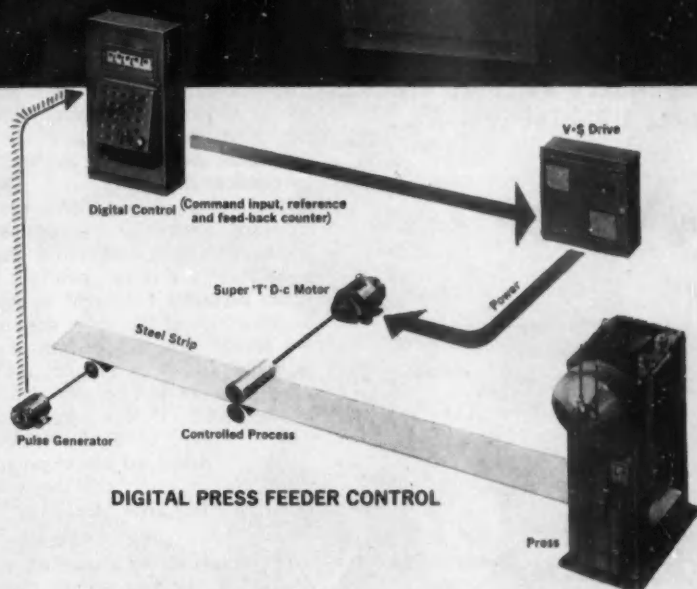
built for the job

Pipe Cut-to-Length

On this pipe fabricating line, the most demanding performance is required by the cut-to-length section. Pipe must be accurately measured and rapidly cut, without stopping the line. A digital regulator measures the pipe to 1/10 of an inch as it goes through the cut-off section. When the selected length is reached, the cut-off V*S Drive rapidly accelerates the carriage to line speed. The pipe is then clamped and cut. The carriage immediately reverses, measuring pipe length as it returns to its starting position. The cut-off carriage weighs 8 tons and is automatically accelerated to line speed in just *four inches of movement*.

Systems Engineering Assistance

Reliance Sales Engineers across the country can give you valuable assistance in systems engineering . . . follow the job through start-up, and render any additional service necessary. Call your nearest Reliance office, or write us direct for further information.



PIPE CUT-TO-LENGTH

Product of the combined
resources of
Reliance Electric and
Engineering Company and its
Master and Reeves Divisions

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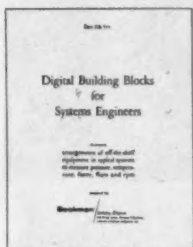
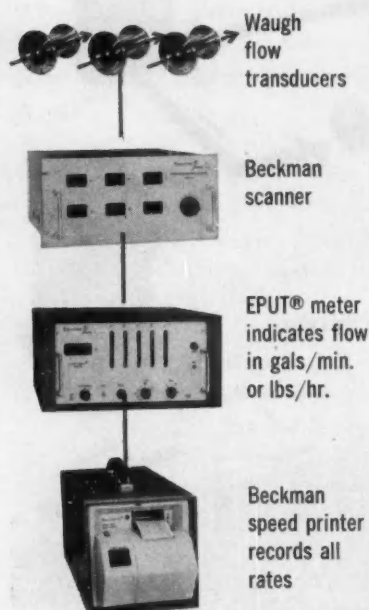


L-1679

MEASURING FLOW?

Now you can assemble complete digital systems using only standard components. All equipment is matched output-to-input to save engineering time and the cost of specially-tailored hardware. The simple system below may be expanded ten-fold in complexity.

ASSEMBLED BUILDING BLOCKS MAKE A DIGITAL SYSTEM...



Write for free 16-page survey of illustrative systems for measuring speed, pressure, temperature, force & flow.

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Richmond 3, California

T 34



FEEDBACK

Tower of Babel still buzzes.

TO THE EDITOR—

In Volume I, Number 1 (September '54) issue of CONTROL ENGINEERING, you discuss the terminology that is to be used for the control engineering field. I imagine that by this time a good deal of work has been done in the terminology area by the various institutes interested in this field and will appreciate information that will indicate where I can obtain, in one volume, information defining the generally accepted terminology definitions for this field; i.e., a control terminology dictionary.

The cover of the same issue of CONTROL ENGINEERING contains one portion of a generalized block diagram describing automatic control functions. I wonder if it might be possible to get a copy of the entire diagram.

I realize that this edition of your magazine has been out of print for some time but will be very grateful if you can send me this information.

R. E. Coulombre
Advanced Development & Systems Dept.
United Shoe Machinery Corp
Beverly, Mass.

It's gratifying to learn that you've dusted off the first regular issue of CtE and found fresh value in it.

There is no single volume containing unified definitions of generally accepted control terminology. The terminology is still in considerable flux. However, several of the technical and trade associations involved in the control field have assembled recommended standards. An unpublished American Automatic Control Council report (copy available from CtE on request) briefly describes the several efforts. A massive American Standards Association activity, Committee C85, was organized in 1955 under M. A. Princi to provide a mechanism for formulation of unified standards in the field. Its product so far is an American Society of Mechanical Engineers report entitled "Proposed American Standard Terminology for Automatic Controls", released in July 1959. Ed.

Can furnish photoduplicates.

TO THE EDITOR—

We have recently received numerous letters from readers of your magazine requesting copies of Russian books listed in the "New Books" col-

umn of CONTROL ENGINEERING, May '60. There is a statement to the effect that these books are available from The Library of Congress.

Although these books are in the Library's collections, they are available only as photoduplicates. It would therefore be of service to your readers if you would indicate in future columns that requests for photocopies of any of these books be addressed to the Photoduplication Service, Library of Congress, Washington 25, D. C.

C. M. Gottschalk
Head, Reference Section
Science & Technology Div.
The Library of Congress
Washington, D. C.

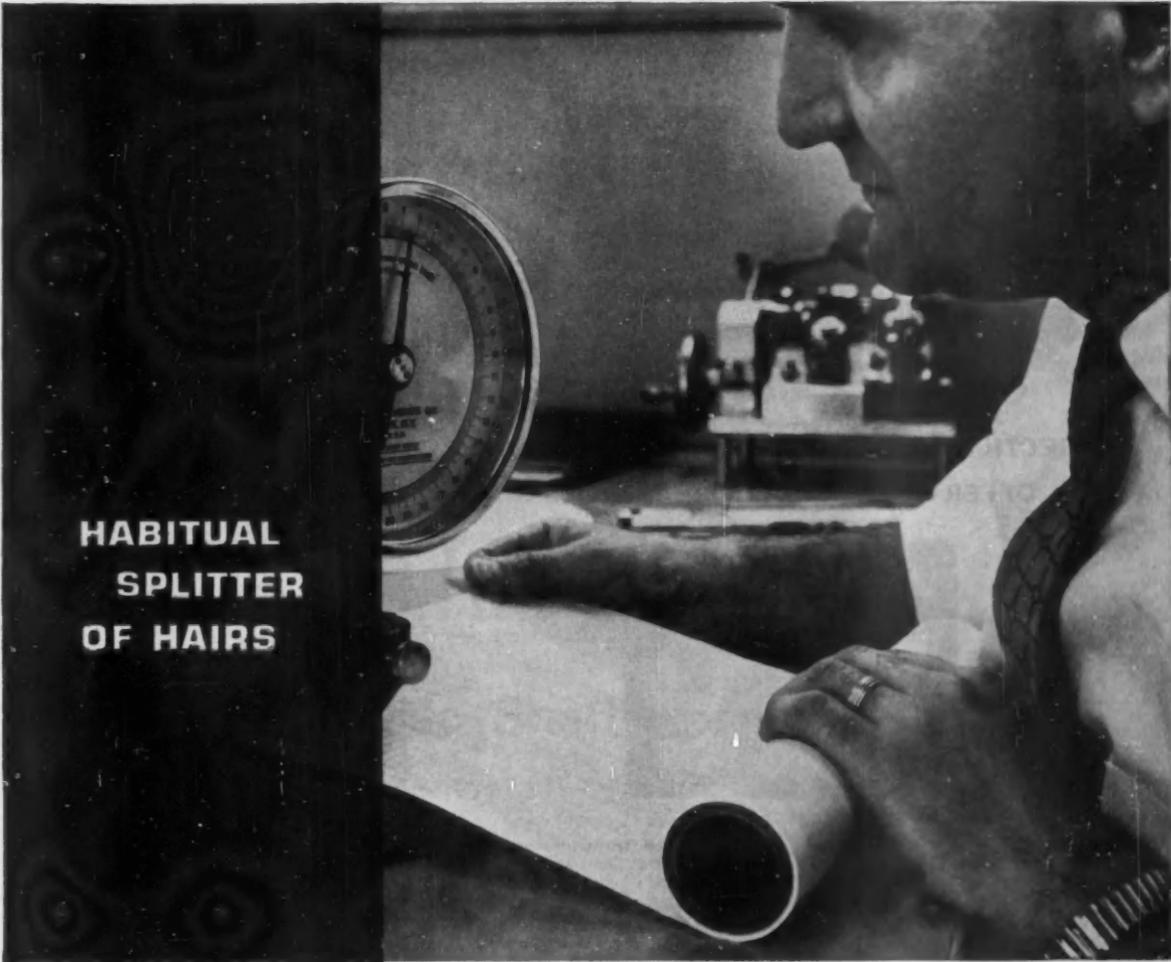
Photoduplication Service will gladly supply order forms that set forth the terms under which the Library will furnish photocopies of the Soviet books we described. Ed.

More Russian impressions.

TO THE EDITOR—

I was very interested, upon returning from the IFAC Congress in Moscow, to read the congress report by Derek Barlow in the August issue (p. 24). In general, I find that his views correspond with my own. However, I have a couple of points not mentioned which may interest your readers.

The computers which we saw in Moscow at the Computation Center of the USSR Academy of Sciences were the vacuum tube machines, the URAL and BESM II, which correspond roughly to the IBM 650 and 704. What interested me very much was that coding for these machines is in terms of numerical fixed-address instructions, just as the first large computers were coded in the U.S. 10 years ago. Neither machine accepts or prints out anything but numbers, and we were told that there are no symbolic assembly systems or any type of automatic coding. Since these are standard machines which have been manufactured in quantity and widely used, automatic coding techniques should be available for these if for any Russian computers. Thus it would seem that, while the computers themselves may be fairly close to U.S. practices (perhaps three or more years behind at most), coding and debugging programs for the machines must be inefficient and time-consuming. We understood, however, that nu-



**HABITUAL
SPLITTER
OF HAIRS**

... because a mil can matter greatly in
RECORDING CHART PERFORMANCE

Even a fraction of a mil can bulk large in the thickness of a recording chart. That's why John Mazurowski and his thickness micrometer are so important to chart users.

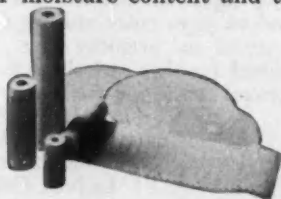
A process change in an eastern oil refinery, for example, called for a longer strip chart in a temperature recorder — but the diameter of the roll could be no bigger than before. GC engineers solved this problem by working with our paper mills to reduce chart paper thickness from 0.00275" to 0.0019" while preserving strength and flexibility.

To make sure our charts meet the requirements of your instruments, GC engineers test paper stock for moisture content and tear-strength, too. This

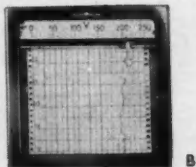
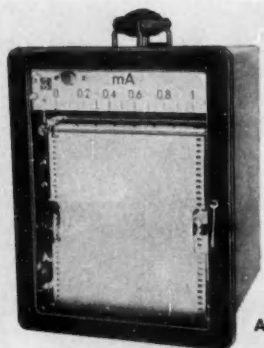
rigid inspection of paper that is produced exactly to GC specifications is a major reason why GC Recording Charts consistently fulfill their promise of accurate performance.

Other reasons for GC quality include our special formula printing inks, our exclusive innovations in plate-making and printing, and the scrupulous humidity control maintained throughout our manufacturing and storage areas.

GC Recording Charts have become standard equipment in more than 5,000 plants today. We stock more than 15,000 different charts—and will design and produce accurate special-purpose charts. Send for our 1960 Stock List — and for sample charts.



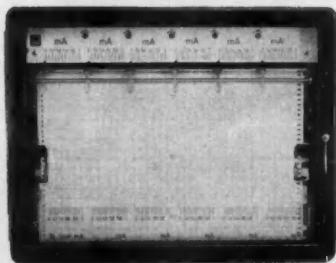
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CHARTS**



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RECTILINEAR STRIP CHART RECORDERS

OFFER YOU 12 BIG ADVANTAGES



1. Moving-Coil and Dynamometer Movements—No choppers, tubes, motors, slide-wires, mirrors . . . provides utmost reliability. AC, DC, and Power movements.

2. Up to 6 Channels Available—Curtiss-Wright Double Size Models are the only Rectilinear Strip Chart Recorders to offer up to 6 channels. Curtiss-Wright recorders provide simultaneous recording of 2 to 6 variables on a single chart in any combination of different types of movements.

3. Sensitivity Down to 250 UA for DC . . . can be extended beyond 250 ua by DC amplifier (optional).

4. Accuracy 1% for Moving-Coil Recorders—Conservatively rated as $\pm 1\%$ of full scale for DC movements. Unusually low friction of pen against chart.

5. Inkless and Ink Recording—Inkless recording is standard equipment on all but Miniature Models, on which it is optional. Cleanest, easiest method . . . a fine metal stylus "burns" the record into zinc coated chart paper. Instantly converted to ink recording.

6. Rectilinear Recording—A patented mechanical linkage changes angular motion of the needle into a straight line, giving an undistorted picture of the signal. Avoids errors, saves time.

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9. Light and Compact Design—Small size and advanced design engineering of movement allows space and weight savings.

10. Dust-proof and Splash-proof Cases—Steel cases decrease effect of stray magnetic fields.

11. Shock-proof Movement—Extra reliability when used in portable applications.

12. Outstanding Workmanship—Improved design and meticulous attention to detail assure highest quality precision performance. All Curtiss-Wright recorders carry a 1-year guarantee.

ILLUSTRATED ABOVE

A. Standard Models. 81 (portable) and 82 (flush). Weight: 19 lbs. $7\frac{1}{2}" \times 9\frac{1}{2}" \times 8\frac{1}{2}"$. \$445.00.

B. Miniature Square Model. (85). Weight: 16 lbs. $5\frac{1}{2}"$ square, $12\frac{3}{4}"$ deep. \$330.00 and up.

C. Double-Size Models. 83 (portable) and 84 (flush). Weight: 26 lbs. $12\frac{3}{4}" \times 9\frac{1}{2}" \times 8\frac{3}{4}"$. \$860.00 and up.

Curtiss-Wright offers you time-proven advantages in precision operation. These Rectilinear Strip Chart Recorders combine advanced design with highest quality workmanship. Moderate in price, these fine precision instruments are rugged and reliable, simple to operate. Write for complete information.

PRINCETON DIVISION

CURTISS WRIGHT

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FEEDBACK

merical techniques for problem solving are well advanced.

I had also heard from previous visitors that transistors were in short supply and available mostly for military work. I visited a radio store in Leningrad which looked very much like radio parts stores in the U.S., although perhaps not quite so well-stocked. Among a large variety of small parts displayed in open counter bins, I found 12 types of transistors priced from 6.5 to 8.5 rubles, which is 65-85¢ at the tourist rate of exchange. There were also a number of glass-bonded diodes which sold for one ruble (10¢).

It is interesting to compare these with prices of typical consumer goods. Prices of consumer goods, when converted to dollars, appeared to be about the same as in the U.S., except that clothes are higher. (Note, however, that average wages are \$100-\$140 per month, so real price is much higher than in the U.S.) It is apparent to me that prices for electronic parts cannot accurately reflect the cost of manufacture and that they must be sold at artificially low prices.

We also found all books to be priced at one-quarter to one-third what they would cost here. For example, a large ($8\frac{1}{2} \times 11$ in., 1,200 pp.) world-wide compendium of vacuum tube and semiconductor characteristics was priced at 28 rubles (\$2.80).

John E. Ward
Electronic Systems Laboratory
MIT
Cambridge, Mass.

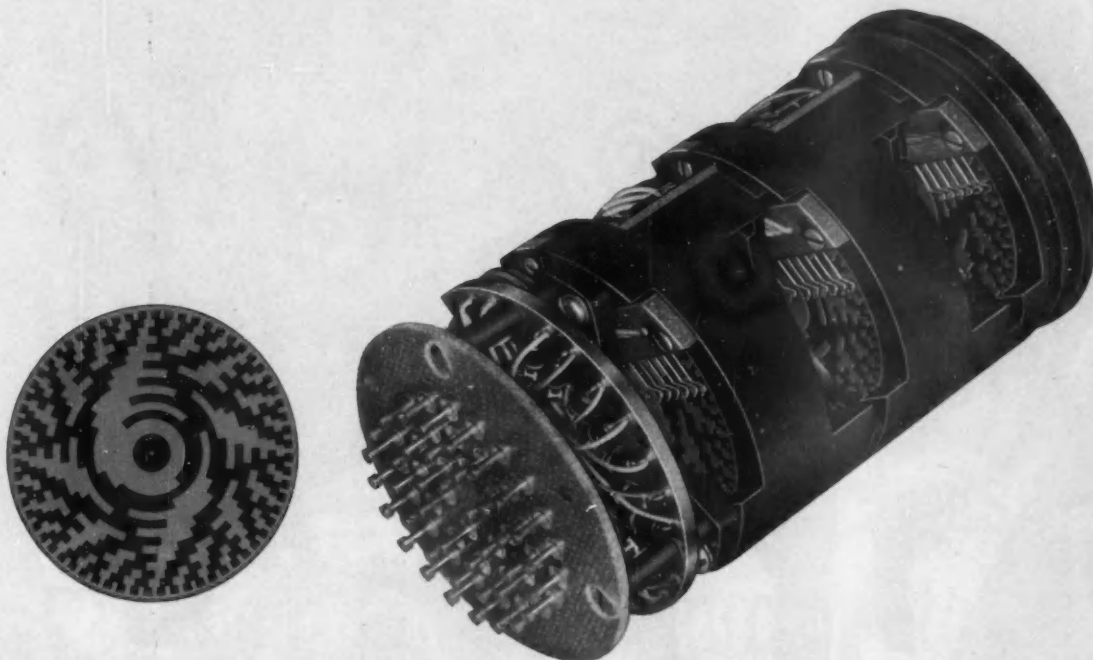
For the record

TO THE EDITOR—

Daystrom was left out of your recap editorial, "Industrial Market Blooms for Data Communication", pp. 59-61, July issue. We should have been included in the "automatic" category, since the function of our communication system is the same as IBM's automatic Saber system.

The only installation to date is at the AEC testing grounds at Idaho Falls, Idaho. It is a tape programmed data collection system capable of scanning up to 6,000 variables at rates of up to 40 scans per sec. After digitizing, the digital information can be punched on paper tapes, utilizing any code, stored on magnetic tape, or transmitted directly via telephone lines to a central computing facility.

John H. Wright
Control Systems Div.
Daystrom, Inc.
La Jolla, Calif.



Norden V-Disc Shaft Position Encoder

—is the smallest size of its type to meet MIL specs

—gives 25% longer life than conventional V-brush type ... at higher speeds

This Norden V-disc design, transferring V-brush logic to the code disc, permits precise single-line brush positioning. Radial displacement of the brushes reduces wear, theoretically by one-half.

LONGER LIFE—IMPROVED PERFORMANCE

- Three brushes in parallel for each contact reduces noise
- V-disc pattern and in-line brushes hold tighter switching angle tolerances
- Precious metal brushes mated to micro-finish pattern disc during run-in
- Meets Military Specifications MIL-E-5272A and MIL-E-5422D

Consider your requirements, then send for complete specifications and drawings for these or any other Norden encoders. Write or call Milford, Connecticut, TRinity 4-6721.

Characteristics of three of Norden standard V-disc shaft position encoders:			
MODEL	ADC-S77-BNRY-X	ADC-13-BNRY-X	ADC-19-BNRY-X
Total count	2 ⁷	2 ¹³	2 ¹⁹
Revolutions for full count	1	64	4,096
Accuracy—1 part in:	128	8,192	524,288
Length (less shaft extension and header)	1 3/4"	2 3/4"	3 15/64"
Life	4X10 ⁶ revolutions at 200 rpm		
Diameter	1.750"		
Mounting	Size 18 Standard BuOrd Synchro Mounting		

RELIABILITY IS DESIGNED IN... AND BUILT IN BY UNUSUAL MANUFACTURING CONDITIONS

Scientists and military electronics experts testify to Norden's unusual quality control techniques. Encoder parts are manufactured, assembled, inspected and reinspected with extreme care in positive-pressure, dust-free, temperature-controlled laboratories. Norden's exceptional design and production facilities are the foundation of encoder reliability. Detailed manufacturing control specifications are available for your inspection.



NORDEN DIVISION UNITED AIRCRAFT CORPORATION

MILFORD DEPARTMENT, WILEY STREET, MILFORD, CONNECTICUT



THE NEW CUTLER-HAMMER SIZE 5 STARTER IS FAR MORE COMPACT THAN OTHERS

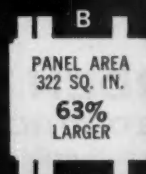
NEW
CUTLER-HAMMER
SIZE 5



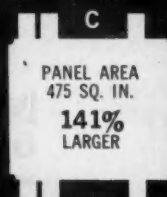
VOLUME
1480 CU. IN.



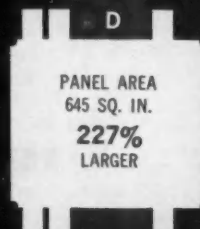
VOLUME 2540 CU. IN.
71% LARGER



VOLUME 2820 CU. IN.
90% LARGER



VOLUME 5750 CU. IN.
224% LARGER



VOLUME 5775 CU. IN.
288% LARGER



Now! A complete line of easy-to-install Cutler-Hammer Starters including a new compact Size 5

7 sizes for use as components or as complete starters

(Size 00, 0, 1, 2, 3, 4 and 5)

Now get all the advantages of Cutler-Hammer's Three Star starter line in seven sizes. You can control motors from fractional hp up to 200 hp, now that the new Size 5 is available.

The new Size 5 starter needs only an eight-inch deep case. Its open dimensions are only 13" wide, 15 3/16" high, 7 1/2" deep . . . and is available as a non-reversing or reversing starter or as a contactor.

Even the wiring's easier. Instead of struggling to force the line and load cables into the lug connectors, the lugs unbolt, and are easily reassembled.

You still get, of course, the famous Three Star advantages that have made Cutler-Hammer Starters so famous: dependable

pivoted armature, vertical contacts that don't collect dust, ease of installation, ease of inspection and maintenance, plus many other features.

Be sure to send for Pub. LO-69-U227 to get all the facts on the complete Cutler-Hammer Starter line.

What's New at Cutler-Hammer?

There's a new spirit here. You can see it in the new products, the new engineering talent, the increased plant capacities. We're ready for the great growth of the sixties so you can be ready to meet the great demands upon your capacities. We'd like to tell you more. Contact the Cutler-Hammer electrical distributor or the Cutler-Hammer sales office nearest you.

WHAT'S NEW? ASK...

CUTLER-HAMMER

Cutler-Hammer Inc., Milwaukee, Wisconsin • Division: Airborne Instruments Laboratory • Subsidiary: Cutler-Hammer International, C. A. Associates: Canadian Cutler-Hammer, Ltd.; Cutler-Hammer Mexicana, S. A.



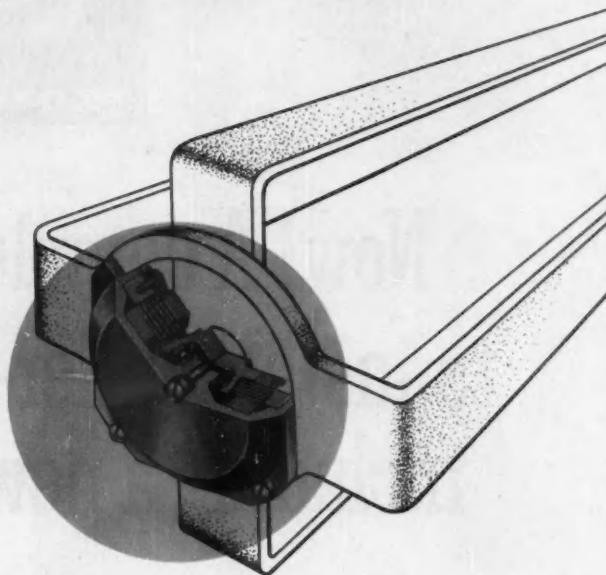
Inland d-c torque motors

provide direct drive servo positioning . . .

NO GEARS, NO BACKLASH

Complete range . . . 0.1 to 3,000 pound-feet

Inland offers a complete line of compact d-c torquers for airborne, shipboard or ground service stabilization and tracking systems. Increased system accuracy has been achieved by mounting the torquers directly on the driven member. This completely eliminates gear backlash and other problems normally associated with gear trains, reduces substantially over-all friction error, and improves the over-all constant of the system. In addition, Inland's d-c torquers combine the compact pancake shape with very high peak torque, low input power, and high angular resolution.



Exclusive commutator and brush rigging design

Inland has achieved this compact pancake shape while maintaining the low-power input to high-torque output ratio of a d-c torquer.

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COMPARE THESE RATINGS WITH A TYPICAL SERVO MOTOR-GEAR TRAIN COMBINATION

	T-2136-A	T-2136-B	T-2136-D
Peak torque, oz. in.	35	35	35
Volts at peak torque, stalled at 25°C	26.0	20.6	33.5
Amps at peak torque	1.6	2.0	1.3
Total friction, oz. in.	0.8	0.8	0.8
Rotor Inertia, oz. in. sec ²	.007	.007	.007
Weight, oz.	9	9	9
Dimensions (inches):			
O.D.	2.81	2.81	2.81
I.D.	1.00	1.00	1.00
Thickness	.63	.63	.63

For complete data on these or other Inland d-c pancake torquers, address Dept. CE,
Inland Motor Corporation of Virginia, Northampton, Massachusetts.



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A SUBSIDIARY OF KOLLMORGEN CORPORATION
NORTHAMPTON, MASS.

George Axelby

puts teeth in the theory

Control theoreticians are likely to take a considerable verbal lambasting whenever engineers concerned with control hardware get together for a gabfest. The usual complaint: the theoreticians aren't presenting techniques that will obviously make the equipment designer's job easier. To many students of control this is not a valid criticism of theoreticians or trends in theory. For that, they turn to a mild-mannered advisory engineer at the Westinghouse Electric Corp.'s Air Arm Div. in Baltimore, Md. George Axelby is a hardware-oriented engineer with a gold-plated appreciation for control theory and its limitations.

During 10 years of industrial and military control work, George Axelby has used bits and pieces of the theory to help design a raft of equipment from aircraft fire control and missile guidance systems to steel mill and machine tool controls. But recently he's found the application of theory is not progressing fast enough, and he feels the theoreticians are mostly to blame.

What's wrong, says thoughtful George Axelby, is that too many theoretical presentations are a sea of mathematics, and most control engineers don't have the mathematical background to interpret what such theory means. "If it is control theory," he says, "something should be controlled. Too often the theory being developed ends in an abstraction instead of an application."

All this, Axelby continues, is hurting the development of the theory too. "Many times if you try out a specific application in today's theoretical presentations, you discover that the theory has proved something trivial. Or the same conclusion can be reached quicker and easier by known routes."

Just back from attending the IFAC congress in Moscow, Axelby had a chance to observe at first hand what Russian theoreticians are doing—of significance because the Russians have always been leaders in theory.

In the U.S.S.R., Axelby believes, application of theory lags the theory itself even farther than in the U.S. "The Russians have fallen into the same trap," he says. "Many of the Russian papers on theory were beautiful exercises in logic but useless from a practical standpoint. The papers on principle of invariance are a good example. They restate some control fundamentals that have been known for a hundred years".


Even though his main interest is in theory—and how to apply it, Axelby's background has been primarily hardware. He got into the control field at



Seth Thomas Div. of Stromberg Time Corp., where he worked first as a draftsman and then a designer, contriving some simple open-loop systems. While doing this, he attended the University of Connecticut and earned his B.S.E.E. degree. He won a Westinghouse fellowship to Yale University to study for his M.S.E.E., joining Westinghouse's newly founded Air Arm Div. after winning his degree. And he's been there ever since. In his present position of advisory engineer he serves as a consultant to project groups in the control field. His strongest capability; taking theoretical concepts and interpreting them to make better hardware.

After collecting papers for an AIEE meeting in 1953, Axelby so impressed his associates in the IRE's Professional Group on Automatic Control with this talent that he was appointed the first editor of PGAC's *Transactions*, a post he still holds. As editor of the *Transactions*, he is exposed to extensive reading that has raised some personal concern because he sees too many theory papers with no tie to past theory. That means engineers have a difficult time evaluating the paper's importance or potential use.

Solving tough control problems for Westinghouse, editing PGAC's *Transactions*, and writing and presenting outstanding presentations on the application of control theory at technical meetings would seem more than enough to keep a man busy full time. But Axelby still finds time for his family and three children, for a hobby of hi-fi, to read the classics, and to play championship tennis in Baltimore tournaments.

We don't mean to sabotage the competition, but the new Benson-Lehner Electroplotter Model J can only be described as revolutionary. This new digital input graph plotter was designed for highest productivity, allowing you to plot more graphs per hour than ever before. Simple to operate, too. Push-button scaling, dialable origin plus automatic input control over scale, origin and printing. Input is fully buffered which permits reading and plotting simultaneously. A completely automatic print mechanism draws lines, prints numbers and prints symbols. You can get plotting speeds of 400 points per minute with magnetic tape input. The Electroplotter J is a handsome, transistorized single unit instrument with a plotting area of 30" x 30". Point plotting accuracy: 0.05% of full scale. For a confidential report on this new little bomb, don't wait another minute. Strike now! Write  **benson-lehner** Corporation, strategically located at 11930 Olympic Boulevard, Los Angeles 64, California.

Speaking of revolutionary plotting, Natasha, my dear...



Newsbreaks In Control

CtE
OCTOBER 1960

● CRT Techniques Position Machining Beam

Windsor Locks, Conn.—By considering an electron beam welding and machining tool as a huge cathode ray tube, engineers at Hamilton Standard Div. of United Aircraft have devised a unique positioning system. The unusual control uses a flying spot scanner, following a prepared pattern of dots, to turn on and off and to position the 150,000-kv cutting beam of the device. Although HSD licenses the electron beam machine from W. German Zeiss Co., HSD-built machines may have this U.S.-designed control when they are introduced next spring.

● Auto Inspector Checks 65 Electrical Components

Detroit—A new inspecting device, programmed by 35-mm film, has slashed electrical component checking time at a major automobile manufacturer by 90 percent, from 150 min to 15 min per car. The device is attached to the battery terminals of the new car while the film program is projected on a screen. An inspector reads instructions for the test on the top half on the screen; a dot pattern appears on the lower half and is bent by a prism into a group of photo cells to instruct a recording device as to what should happen to the component being tested when it is operated. Results of the test are recorded on punched tape as well as indicated to the inspector.

● Surgeon's Data Logger

Los Angeles—New digital medical data logger has been developed by Starling Corp. so a surgeon may read several indicators of a patient's condition on a wallboard during an operation instead of having to ask assistants. Transducers placed on the patient are directly connected to the logger to present such information as patient's blood pressure, temperature, respiration, etc. Device will be marketed within two months.

● Britain to Set Up Detecting Element File

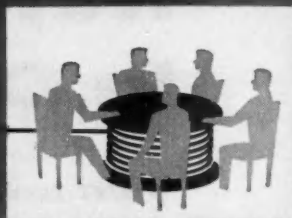
London—British Scientific Instrument Research Association (BSIRA) will open a Detecting Elements Bureau next year to catalog data on commercially available detecting elements. In its files, open to any inquiring engineer, the bureau will maintain a listing of available elements including such data as the specifications, principle of operation, input and output, accuracy, discrimination, frequency or response time, operating temperatures, dimensions, manufacturer, special features—up to 200 parameters.

● TV Control for Freeways

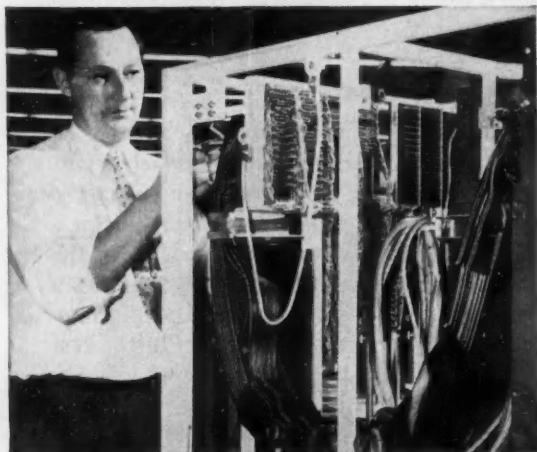
Detroit—Fourteen television cameras are being mounted on the John C. Lodge Freeway to allow better control of traffic. The pictures will be transmitted by wire to a central control room where a traffic dispatcher will monitor traffic—closing lanes, reducing speed limits, and shutting off entrances as traffic flow dictates.



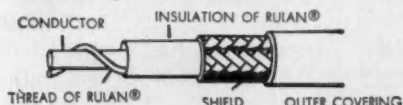
WIRE AND CABLE ROUND TABLE



Flame-retardant insulation of RULAN® used by IBM has five outstanding qualities



Approximately 1000 feet of cable are installed in each new IBM 7090 computer. Only the most dependable of insulating materials could meet the rigid requirements.



The unique design consists of a thread of RULAN spiraled around the conductor to provide for an air space between the conductor and insulation.



IBM's new 7090 fully transistorized data-processing system is the most powerful system to be marketed commercially. It has computing speeds more than six times faster than previous systems...can read and write 3,000,000 bits of information a second.

AN air-spaced ribbon cable, insulated with Du Pont RULAN flame-retardant plastic, is used in the new 7090 Data Processing System, manufactured at the huge IBM plant in Poughkeepsie, N. Y. Performing such feats as reading and writing three million units of information a second, the 7090 relies heavily upon its electrical system. IBM selected a dependable cable insulated with RULAN, developed and manufactured by William Brand—Rex Division of American Enka Corporation, Concord, Massachusetts.

The most important consideration is the flame retardance of the insulation of RULAN. The possibility of fire in such an important and expensive machine, although slight, is not worth risking. Thus this insulation, with an excellent self-extinguishing capacity, proved acceptable. RULAN was also chosen because it has a low dielectric constant over a wide frequency range. Its excellent dielectric properties give RULAN still another useful quality—it can be thinner than many other materials.

Because the installation required that the cable bend around corners, it had to be flexible and have a good radius of bend. Again RULAN proved wholly acceptable. With approximately 1000 feet of cable installed in each machine, cost is an important consideration. And RULAN proved to be lower in cost than other suitable materials with the same properties.

You may find one of the Du Pont plastics will help you solve your wire and cable problems. Find out how by writing to your wire and cable supplier, or to: E. I. du Pont de Nemours & Co. (Inc.), Dept. E-10, Rm. 2507A Nemours Building, Wilmington 98, Delaware.

Du Pont does not manufacture wire and cable, but supplies thermoplastic resins for insulation and jacketing.

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Pocket-Sized Reactor for Direct Conversion

CANOGA PARK, CALIF.—

A small nuclear core—7 in. high, and 7 in. in diameter—has gone critical here as part of a study to produce a small reactor for the direct conversion of nuclear energy into electricity. Designed to be part of an auxiliary power plant for space vehicles, the reactor was built by Atomics International Div. of North American Aviation for the U. S. Atomic Energy Commission.

Fuel and moderator in the experimental core is a homogenous mixture of uranium 235 and zirconium hydride. In the finished total system, to be tested early next year, electricity will be generated by the flow of heat from the reactor through thermocouples which surround the core. The system is expected to generate 300 watts and will be designated SNAP 10 (for Systems for Nuclear Auxiliary Power).

Utility Programs Logger with Magnetic Drum

ROCKY REACH, WASH.—

Two solid state digital information systems at the new Rocky Reach Hydroelectric project will be programmed by a magnetic drum, the first such non-computer industrial application of drums. Built by the Bailey Meter Co., the system will measure and scan 110 variables at the rate of 1 per sec., and log all points once an hour.

Scanning and logging sequence is established by storing each input point relay number in the desired sequential order on the drum. Then setpoint values with high and low values are stored on a separate sec-

tion of the drum, but in the same sequence as the input point relay numbers.

Typical word length is 20 binary bits, with all representation in binary-decimal. Twenty binary bits may represent a "command", the sign and value of a variable, or the sign and value of an alarm setpoint.

Come Home Service for Control Computers

LA JOLLA, CALIF.—

Instant factory service for control computers is being offered by the Control Systems Div. of Daystrom, Inc. With this unique service, a control computer in the field is connected by telephone wire with a special service console in the Daystrom factory.

If trouble develops, factory engineers can take control of the computer over the line and perform skilled trouble shooting. The Daystrom factory engineers can instruct technicians at the computer site to make special measurements and to perform routines to correct any malfunctions.

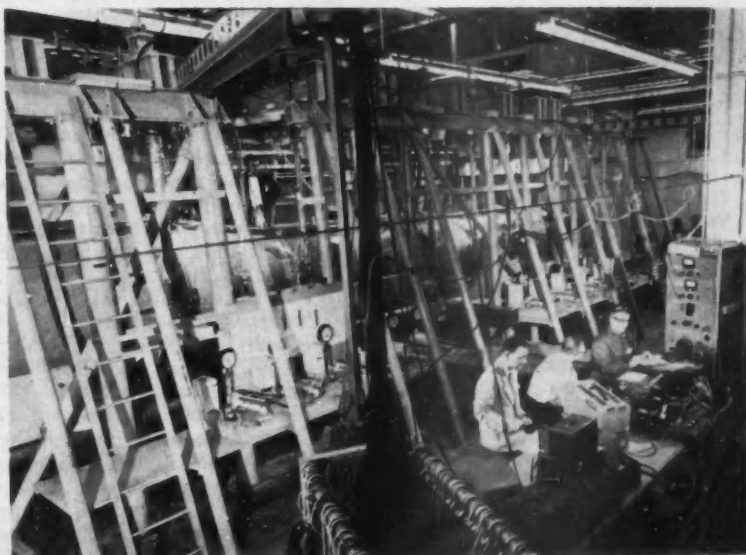
To illustrate how much data can be sent to the factory, the transmission equipment will reproduce a cathode ray oscilloscope display on a tube at the factory console, reproducing the wave form at any computer point which the factory engineer wants to observe.

Daystrom has dubbed the new service "Come-Home" system because it brings Daystrom computers and data loggers "home for servicing".

To use the new service, a customer has to install a special console, which Daystrom will lease on a monthly basis, with or without a man-in-residence service contract. The yearly rental of the system is less than the salary of one computer engineer required for on-the-spot trouble shooting.

Progress in Minuteman

Minuteman, solid-propellant intercontinental ballistic missile, is undergoing dynamic testing at Boeing's Aero Space Div. This giant simulator (photo at right) imposes the same stresses on the missile's frame as actual conditions from launch to burnout of all three stage engines. Object of such tests: to assure that missile's frame can take the strain imposed on it. Meanwhile, over a thousand miles away, Autonetics Div. of North American Aviation has completed the first inertial guidance package for the Minuteman.



A CtE NEWS ROUNDUP

Duplicating the Performance of Biological Systems

Computers as currently designed cannot easily solve an important type of problem: nonnumerical data processing. What is needed is a more human-like system. Although the payoff in usable hardware is five to 10 years away, CtE reports some of the problems and how they are being attacked as interest blossoms in this intriguing new field.

Design of electronic general purpose digital computers, say avant garde scientists, has reached a saturation point. Future improvements may produce a machine that can perform arithmetic operations about 20 times faster than the high speed IBM Stretch the U.S.'s fastest machine, but the computer as currently envisioned will never be able to solve efficiently one of the most intriguing groups of problems: those that involve nonnumerical data processing. For problems such as pattern recognition, speech recognition, machine translation of languages, photo interpretation, or the control of large complex systems a far more sophisticated system is required, machines that perform with near human-like behavior.

After several years of ground-breaking investigation, activity in biological-oriented devices is now starting to blossom. Dr. M. C. Yovits, head of the Information Systems Branch of the Office of Naval Research, which has sponsored many of the early studies in this field, estimates that almost \$1 million will be spent on such research this year. Now the Air Force is launching a new program of basic research that will surely increase the activity (see box).

• **The definition**—By a biological machine, researchers mean a device that is modeled after a biological organism and that is capable of adjusting itself by changing its organization or structure as its environment changes—with a minimum of advance information and based on past experience. Such systems have been called by many other names too. At ONR, for example, they are called *self organizing systems*, and the Air Force has coined the name *bionic systems* to describe them.

Biological organisms have intrigued researchers as models for machines because they adapt to changes in environment so well.

The human body, for example, is full of adaptable systems—that keep the temperature of the body constant at 98.6 deg C regardless of outside temperatures, that keep the amount of alkaline in the system at the same concentration, and that keep the blood composition the same. The ultimate goal of this research is to build a machine that exhibits the intelligence and reliability found only in high types of biological life.

To reach this goal, investigations have taken several apparently diverse directions:

► **Studying** (more accurately, scrutinizing) biological organisms such as the eye, the ear, and the brain. An outstanding example is the report "What the Frog's Eye Tells the Frog's Brain" by a group of MIT researchers.

► **Proposing and analyzing** theoretical learning systems, based on the fundamentals of learning as propounded and uncovered by psychologists. The Perceptron of Cornell Aeronautical Laboratory is one.

► **Mechanizing** these systems to perform a specific function.

► **Developing components** to perform the same functions as biological organisms; probably the best publicized is the attempt to duplicate the neuron, the mysterious but miraculous cell of the nervous system.

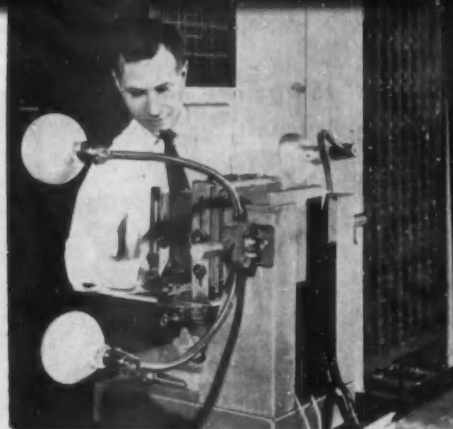
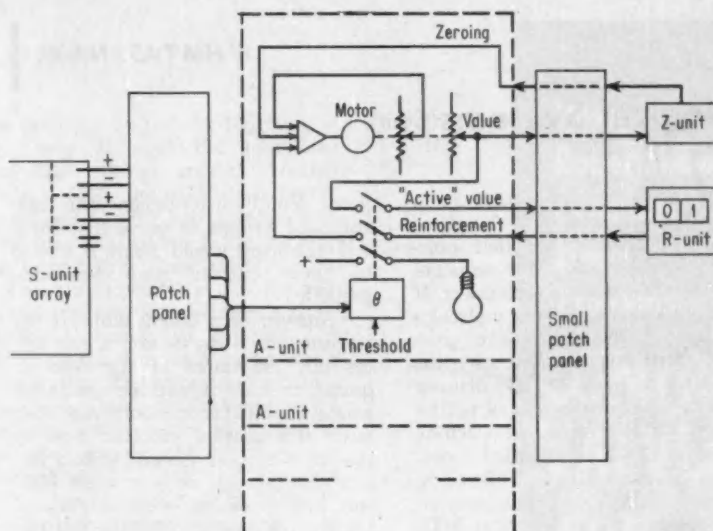
• **Combines many talents**—The spectrum of workers in the field reflects the multifaceted effort. There are mathematicians like MIT's Oliver Selfridge, Marvin Minsky, and John McCarthy and Carnegie Tech's A. Newell, J. C. Shaw, and H. A. Simon; physical scientists like ONR's Marshall Yovits and University of Chicago's Peter Green; embryologists such as R. Auerback of the University of Wisconsin; philosophers like A. N. Burks of the University of Michigan; neuro-physiologists, the most famous of whom are W. McCulloch of MIT

and England's Ross Ashby who started much of the interest in learning machines with his famous book *Design for a Brain* (John Wiley, 1950); and psychologists like Frank Rosenblatt, Cornell University.

Working with this potpourri of researchers are a group of highly skilled engineers, whose training is mainly in electronics: Scott Cameron of Armour Research Foundation, Hugh Crane of Stanford Research Institute, D. Willis of Lockheed Aircraft Co., J. Hawkins of Aeronutronics (a division of the Ford Motor Co.), H. Von Foerster of the University of Illinois, Gordon Pask in Great Britain, B. G. Farley of MIT, and S. Goldman of Syracuse University, to name only a handful.

• **The Perceptron**—Frequently the directions overlap in a project as do the people. A good example is the Perceptron, an adaptive device to read print and probably the best known of the U.S. learning machine experiments by virtue of its successful demonstration in June. It was built at Cornell Aeronautical Laboratory with ONR and Air Force support. Psychologist Frank Rosenblatt conceived the Perceptron concept: visual characters are converted to a large number of electrical signals in a retina; each source stimulation is connected at random to association units (A-units)—more than one connected to each association unit; as a result of summing up these signals, certain association units are activated and the alive A-units then trigger the proper response units to identify the character.

In the evolution of the Mark I Perceptron, mathematicians first converted Rosenblatt's theory to equations, put it in numerical form, and simulated the Perceptron concept on a digital computer. And, to convince skeptics, engineers then mechanized the concept in the machine success-



Perceptron, a self organizing reading device, as schematic and in hardware. S-units are photocells arrayed in matrix behind camera. Association units are in open rack (third from right).

fully demonstrated (see photo).

But one key problem in the Perceptron project is yet to be solved. That's the development of an inexpensive component to perform as the neuron of the system, a role played by the association units. In the first Perceptron, motor powered potentiometers served as A-units, but they are too large and too expensive, limit the

machine to only 512 A-units. Now under development is a magnetic A-unit made with the Aeronutronics BIAX unit, a tiny core of ferrite material. This will make it possible to build a Perceptron with thousands of A-units.

Even with this accomplishment, a really usable machine is still far off. What's desired, says ONR observer

Yovits, is a machine with the equivalent of a billion neurons, meaning a component that would cost a maximum of one cent a piece. Such a machine could be trained to read any type face, even if it were rotated or distorted, it could even be designed to read handwriting.

• **Search for the neuron**—The search for the small inexpensive component

The Air Force's Program in Bionics

At the Wright Air Development Div., the Air Force's newly accelerated bionics program is being directed by Major J. E. Steele, an air surgeon whose medical specialties are neurology and psychiatry buttressed by graduate school training in electronics and mathematics. Steele defines Bionics as "the science of systems that act like living organisms". His Air Force program: the application of knowledge of the life sciences to engineering problems.

As an overall objective, WADD's engineering-minded Air Surgeon aims to bridge the gaps between biologists, mathematicians, and engineers. He hopes to stimulate biologists to put key parts of their knowledge into a form that mathematicians can understand and translate into realistic mathematical expressions that engineers can then convert to hardware.

For fiscal 1961, the Air Force Program, up to \$1,000,000 from last year's \$40,000, will have five main projects: signal analyses, adaptive servomechanisms, biological components, neural networks and information processing. Here's a rundown of what the Air Force hopes to accomplish:

• **In signal analysis**—To study how to obtain useful information from a time series of a single value function. To identify the analytical methods used by living organisms to receive single-valued stimuli (such as the technique by which the ear recognizes a word) and to apply them to engineering. At Mississippi Southern College, for example, Dr. Robert Peters is attempting to identify the psychological parameters of sound. Although pitch and volume are variables frequently associated with sound, they are little help in the mechanism of identifying words.

• **In adaptive servomechanisms**—To measure characteristics of living systems as duplicated on a model which has been built at WADD for the better design of servos. For example, Dr. Steele has observed that living systems always use two feedbacks—force and location feedback—and the relation between the two is an important factor. Work is underway both at WADD and Ohio State University.

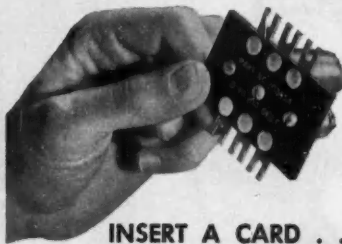
• **In biological components**—To build a device that will perform many of the functions of the neuron. First WADD sponsored a project at the University of Michigan to summarize the biological knowledge about the neuron. Now, Major Steele hopes to formalize key parts of this knowledge, and put it in mathematical form.

General Electric's electronic research laboratory is building a piece of hardware to duplicate some of the functions of the neuron. It will be a practical information system about the size of a transistorized portable tape recorder, and the unit will have 45 inputs and a single output which can increase or decrease but never become negative. Connected with other electronic components (such as a tapped delay line, capacitors, and resistors) it could be an adaptive filter.

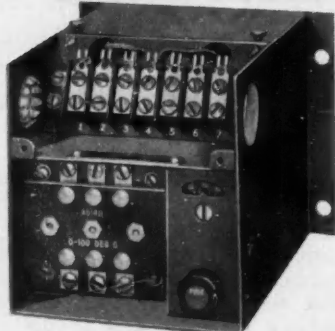
Major Steele expects such a component eventually to be part of a system that will be able to do such sophisticated chores as making sense out of patterns or detecting missiles from decoys.

• **Neural networks and Information processing**—Not yet underway. Steele hopes to do such things as study a neural network that accomplishes a specific function—example: the retinal network of the human eye.

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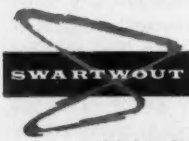
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Highly sensitive, the fully-electronic Swartwout Resistance Thermometer temperature system is adaptable to full-scale temperature spans as small as 3°F. It can indicate, record, or control. With slight modification, or auxiliary equipment, it will add, subtract or average temperature . . . even control the ratio between two temperatures, or between temperature and another variable.

All this is done with electronic speed. Data is transmitted instantaneously . . . no time-lag no matter where temperature elements are located.

The operational ease, functional flexibility and simplicity of the Resistance Thermometer are characteristic of the entire line of Swartwout Autronic Instrumentation.

For details on the Resistance Thermometer, request Bulletin A-706-B. SWARTWOUT DIVISION, CRANE CO., Hooksett Ind. Park, Manchester, N. H.



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Biological Systems(Cont)

to perform like a neuron crops up in any listing of biological machine studies. Researchers hope that molecular electronics—one piece semiconductor systems—may be the answer. If it were possible to use the molecules of matter as the neuron-like component, they hypothesize, scientists might have as many as 10^{24} neurons in a gram molecular weight of matter—enough for any biological machine envisioned. ONR has awarded a contract to Stanford Research Institute to research such a molecular neuron. Similar studies are underway at MIT and under Air Force direction.

Another approach to the component problem is the neuristor proposed by Stanford Research Institute's H. Crane. Psychoneurologists say Crane's concept in theory exhibits many of the properties of the neuron and its construction appears feasible. Explaining the neuristor in simple terms is not easy. One researcher says it is an extended type of circuitry that will carry electrical impulses, with no attenuation, down a line (like a delay line) until the line branches; then the signal travels in both directions undiminished. Once a pulse has passed, the line becomes refractory and cannot carry another pulse. As many two-headed branching points as desired can be theorized, so the neuristor is capable of performing many logic functions.

The nonconductive capability of the neuristor, after a pulse has passed, extends in area so that passing a pulse down one line makes it act as a negative gate, blocking the passage of a pulse down another line which is located close to the original one. In one view the neuristor is a "sea of energy" in which pulses are moved about at constant speed or blocked.

ONR believes the neuristor may lead to the building of sophisticated machines and is supporting research at SRI and Stanford University.

Still another attempt to duplicate the human neuron is the electronic circuit built by Von Feurster at the University of Illinois, which also has a large group active in biological machine research. By connecting several transistors and resistors together, Von Feurster was able to duplicate several of the functions of the neuron.

Obviously the use of the transistors, which cost from \$2.50 to \$50, precludes this "neuron" from satisfying the requirement of costing at most one cent. That was not its main pur-

pose. Von Feurster designed his transistorized neuron to prove that some self-organizing would result if several of these circuits were combined properly.

• **Analysis on a billion units**—If the performance of the neuron is ever successfully duplicated at the cost required, the kind of machine envisioned would use billions of them. And that raises still another problem: how to analyze electronic circuits with a billion components, or even more difficult, how to analyze a billion circuits. Dr. Ross Ashby, who has studied the adaptive processes of the human brain and tried to explain them, is now trying to determine the dynamics of such a large system, and what would happen when such a large number of components are brought into one unit.

At the National Biomedical Research Foundation, Dr. R. S. Ledley has undertaken a Herculean task: the analysis of a billion gate circuits. Ledley will attempt to hypothesize mathematically how to put a billion gate circuits together.

• **Mathematics ploy**—A good portion of the research in the new field involves mathematics, an attempt to put a theory or a design into mathematical terms. At MIT, for example, where such research is being performed at the Research Laboratory of Electronics and at Lincoln Laboratories, a lot of work is mathematical, ranging from the invariance ideas of M. Minsky to the heuristic programming of J. McCarthy.

Heuristic programming is also the subject of study at Carnegie Tech by mathematicians Newell, Shaw, and Simon. A normal program instructs a machine exactly what to do; a heuristic program's instructions are considerably less precise, such as culling out a few possibilities from many possible moves in a game of chess. It is as if the program were capable of hunches.

• **Wonderful property filters**—Another area of MIT research that looks promising is the study of property filters. Animals have demonstrated that many of the enviable capabilities of living organisms can be traced to such filters, which screen out certain types of information and allow others to pass unimpeded. At MIT under Dr. W. McCulloch, for example, a study of a frog's visual and audio mechanisms have indicated the existence of strong property filters. One filter permits the frog's eye to pick

WHAT'S NEW

WHAT'S NEW

out sharply a fly and the trajectory of the insect although the amphibian sees other things poorly. Another property filter, the MIT study found, allows one frog to hear another with great accuracy, although the amphibian cannot hear many other sounds.

The property filter is also the subject of study by Von Feurster's group at the University of Illinois. The use of such a filter as a screen would simplify the data processing job of a learning machine in the same way a property screen before the retina of the eye screens out many signals received on the eye and transmits only a few thousand to the brain.

• **Crystal growing**—Some other biological machine work has to be classified as pure basic research, and even the researchers are not quite sure where it will lead. In England, for example, Gordon Pask has been studying how crystal structures are formed. He has placed a number of electrodes in a bath of a ferrite solution and studied how metallic threads are formed when a current is passed through the solution, with varying voltages and even changes in direction. Stafford Beer is also experimenting along these lines.

Behind Pask's work is this belief and question: all computers today operate on a statistical basis, but does nature operate on this basis? With his experiments Pask is attempting to determine how an organism might respond to crises with the ultimate goal of applying the same approach to the solution of industrial problems. His work may also lead to some ideas on how to design circuits for biological machines.

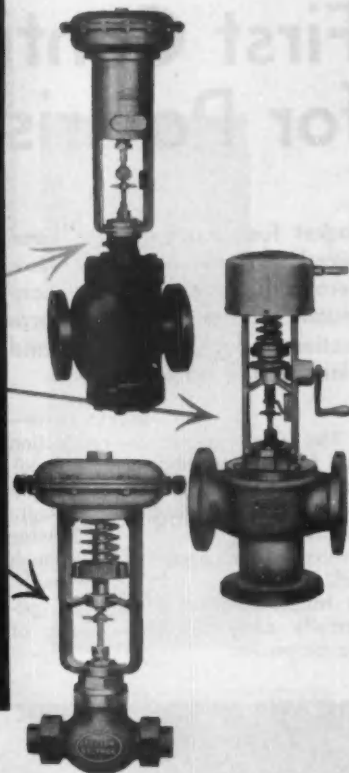
• **But when?**—The big question still is when will biological machines be usable enough to perform a reasonable function, like the control of a complex process. ONR's Yovits feels some simple machines may be available by the end of 1965, but the elusive component to imitate the neuron is at least 10 years away.

These machines will evolve slowly as a natural extension of technology. The concept of adaption goes back to the servo-mechanism which can be considered a simple electromechanical self-organizing device that minimizes an error. A more sophisticated device is the adaptive servo, and more recently, adaptive systems, capable of major system changes with changes in environment. Machines with human-like behavior are a natural extension of such systems.

—Lewis H. Young

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First Continuous Production for Polaris Propellant

Rocket fuels have always been mixed in batch processes. Now Aerojet has developed a continuous process to speed up production, reduce labor costs, and minimize the hazards.

SACRAMENTO—

The first continuous production line for mixing solid rocket propellant has gone on stream at Aerojet-General Corp.'s sprawling Sacramento facility. Built to supply the growing Polaris missile arsenal with enough fuel, the new line uses on-line analysis instrumentation to end the potentially dangerous batch-mixing of the propellant.

Until Aerojet put Polaris propellant production on a continuous basis, nobody felt it could be justified. The reason: development work in the rapidly changing missile industry leads to continual changes in formulations, and the specifications that are set must be followed exactly. But the speedup in the Polaris program dictated that Aerojet do something radical to meet delivery dates.

Last year when the new schedule was made known, company engineers set out on a crash program to develop a continuous production method. An additional benefit has been realized because the new method reduces propellant variability by providing a smoother mix.

Continuous production has been applied to the most critical part of propellant production: the combination of premix, commercial polyurethane, and ammonium perchlorate oxidizer. (Blending the premix is not under automatic control. The most classified segment of the propellant, because it determines the burning rate, the premix is composed of five solid and three liquid components. In the over-all production process there is sufficient time between making the premix and final propellant mixing so that automatic control is not justified.)

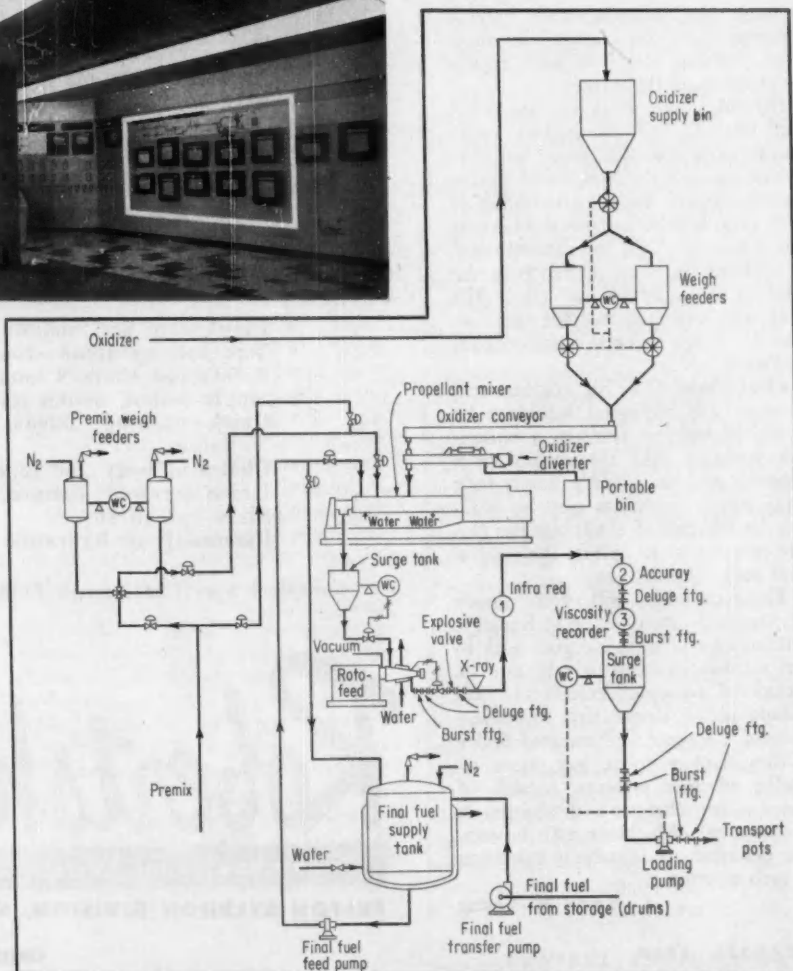
In the final mix the control problem is magnified because the specifications are so tight and the cost of fail-

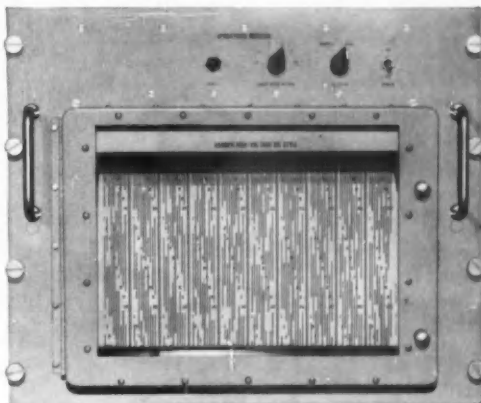
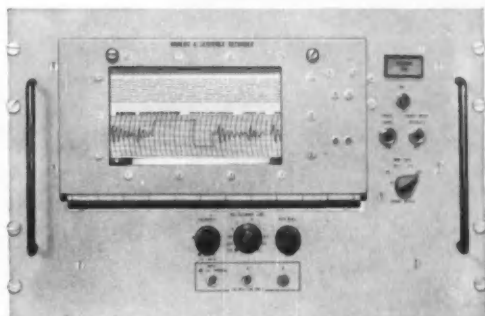
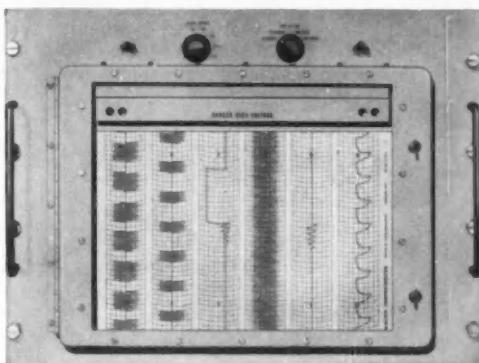
(Continued on page 36)



Control room of continuous propellant line; recorders connected to on stream analyzers are in boxed area. There are two production lines so recorders from one are above those for the second line. Variables recorded (from left to right): temperature, infrared absorption, chlorine concentration, density, and viscosity.

Schematic of final mixing with position of analysis instrumentation indicated: 1) infrared cell for spectrophotometer, 2) nuclear density gage, and 3) viscosity recorder.





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These all stainless steel valves are especially suited for use on missile ground support equipment.

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For Immediate Delivery . . .

World's largest stock of Solenoid Valves. A complete Solenoid Valve Stock List will be sent to you with your copy of Catalog No. 202.

ASCO Valves Automatic Switch Co.

56-D HANOVER ROAD, FLORHAM PARK, NEW JERSEY, FRONTIER 7-4800

CIRCLE 35 ON READER SERVICE CARD

AUTOMATIC TRANSFER SWITCHES • SOLENOID VALVES • ELECTROMAGNETIC CONTROL

←CIRCLE 34 ON READER SERVICE CARD

ASCO®



Performance of This New Accelerometer Is Spectacular!

And CEC's Type 4-202 Strain Gage Accelerometer is also the smallest on the market...measuring just one cubic inch.

Here are some of the performance characteristics that make the 4-202 infinitely superior to any other linear unbonded strain gage bi-directional accelerometer:

Its cross axis response is unusually low...its resonant frequency is unusually high—and there's extremely little damping change over a temperature range of -65°F to $+250^{\circ}\text{F}$.

The 4-202 is the smallest temperature compensated instrument you'll find anywhere for measuring accelerations perpendicular to mounting surfaces. It's available now in a range of $\pm 5\text{g}$ to $\pm 500\text{g}$.

For more information, write for Bulletin CEC 4202-X2.

CIRCLE 36 ON READER SERVICE CARD

Transducer Division

CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

A SUBSIDIARY OF Bell & Howell • FINER PRODUCTS THROUGH IMAGINATION

WHAT'S NEW

ure so high. The final product has to meet stringent density and viscosity requirements, and the correct proportions of the three major materials must be maintained exactly.

• On-stream analysis—A battery of unmanned on-stream analyzers placed at the discharge of the last mixing cone performs the measurement job. Density is measured by a radioactive nuclear gage. Gamma radiation from a radioactive cesium source is passed through the material, and its absorption supplies a measure of density. Viscosity is measured by a standard sonic device, a Bendix Ultraviscoson, in which viscosity is determined by measuring the damping of a vibrating reed. The proportion of oxidizer is determined by monitoring the amount of chlorine (in the ammonium perchlorate oxidizer) with a Perkin-Elmer infrared spectrophotometer.

Information from the analysis section feeds into a central control console. By watching readings on the console, an operator can divert out-of-spec propellant or shut the line down so that corrections can be made if the material runs off-spec. No on-stream adjustments will be made, however, because the input of chemicals is so carefully controlled manually, any analysis showing incorrect output indicates a gross error made earlier.

The process has a few closed-loop controls. One is a temperature control which maintains the temperature of the propellant at all times within one degree of 100°F . Another is automatic weight control in the final surge tank.

• Advantages add up—The big advantage of the continuous system is increased production. But there are some subsidiary benefits too. Aerojet expects the new line will cut labor costs 80 percent, from 18 cents a lb for batch mixing to under 5 cents.

The continuous line introduces no more than 30 lb of pyrotechnic material into the mixer at any one time. This results in several benefits too. In case of improper compounding, no more than 200 lb of propellant is lost—the amount in the mixer and in the rotofeed where the rubbery compound passes from the mixer to be degassed.

And it is far safer. Since the mix is only dangerous when "heat and work are put into it", the 30-lb limit in the mixer practically obviates a disastrous explosion. An automatic deluge system in the mixer can quench the flames of such a small amount almost instantaneously if a fire should break out. Under the old batch system, pro-

KOLLMORGEN EYE SITE FOR

ATLAS. Kollmorgen's Type 501 Telescope has been specified to boresight the tracking antenna of the General Electric radar command guidance system for the Atlas ICBM. Type 501 incorporates unique features which permit pinpoint precision in sighting and collimating. Reticles at both ends of the scope allow you to sight on infinity, transfer the eyepiece to the other end of the instrument, and sight back azimuth accurate to one second of arc without moving the telescope body. It is possible to focus from infinity to 500 feet with no deviation in the line of sight.

This is a typical Kollmorgen achievement in the design and production of highly precise optical instruments and systems for industry and defense.

Send for our illustrated, twenty-four page brochure describing Kollmorgen experience, skills and facilities.



KOLLMORGEN
CORPORATION

NORTHAMPTON, MASSACHUSETTS

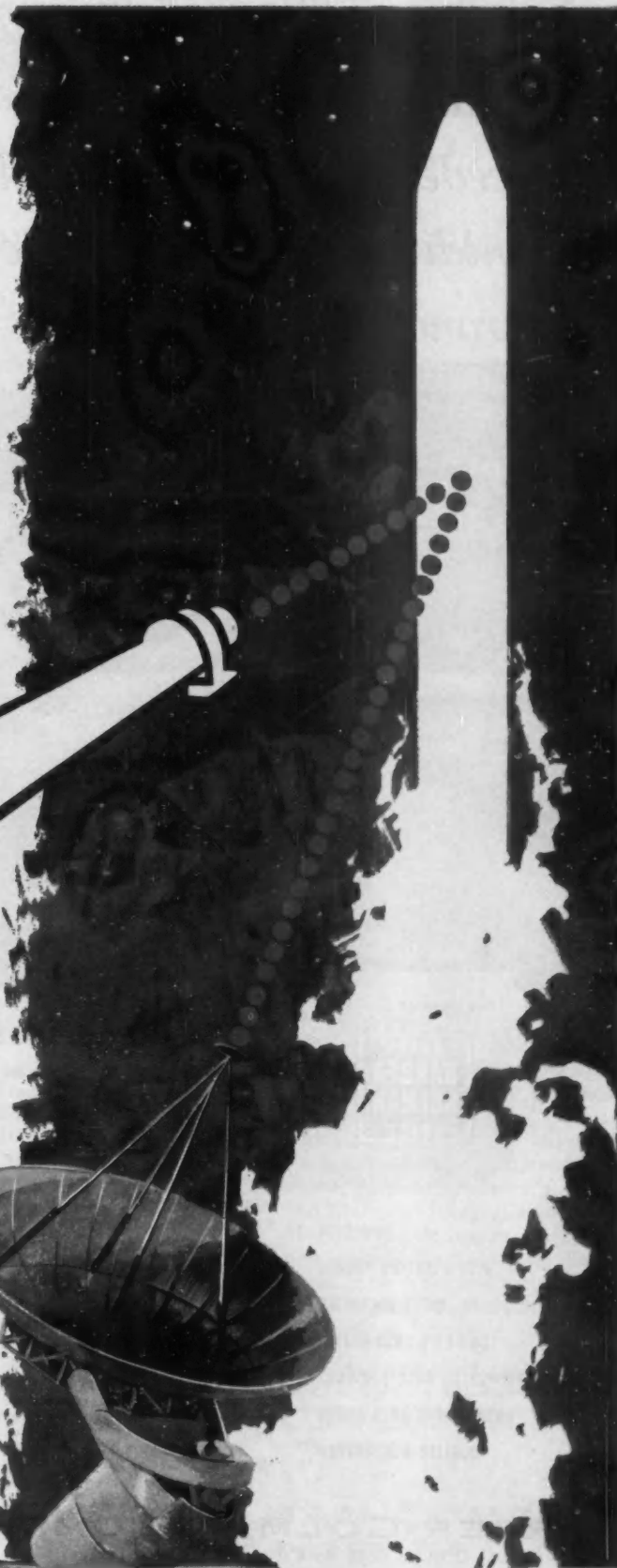
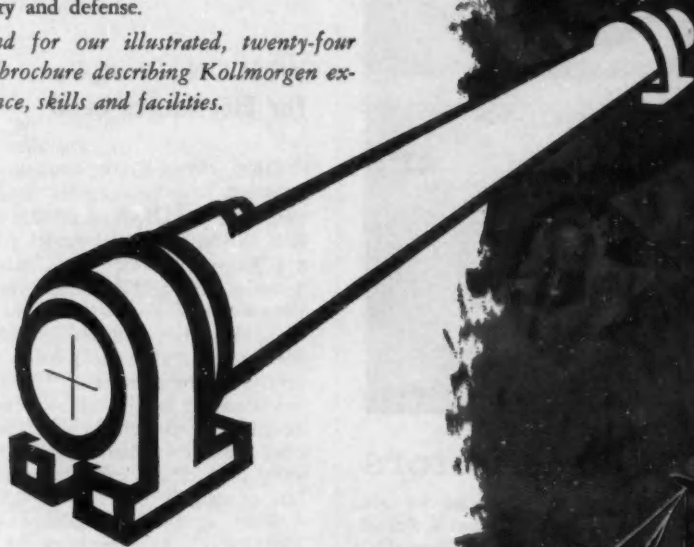
NUCLEAR REMOTE VIEWING EQUIPMENT • SUBMARINE PERISCOPES • OPTICS • BORESCOPES • MOTION PICTURE AND TELEVISION LENSES • PRECISION OPTICAL INSPECTION AND ALIGNMENT DEVICES • ELECTRONIC CONTROLS AND COMPONENTS • NAVIGATIONAL AIDS

WESTERN TECHNICAL REPRESENTATIVES
COSTELLO & COMPANY, LOS ANGELES, CALIFORNIA

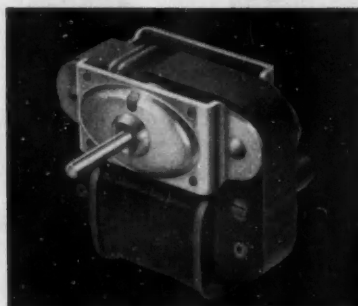
Resumes invited from qualified optical engineers

OCTOBER 1960

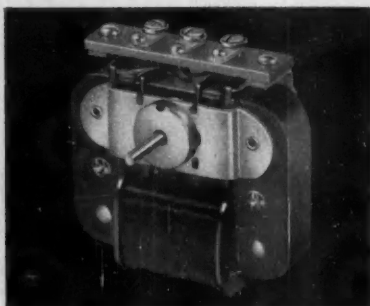
CIRCLE 37 ON READER SERVICE CARD 37



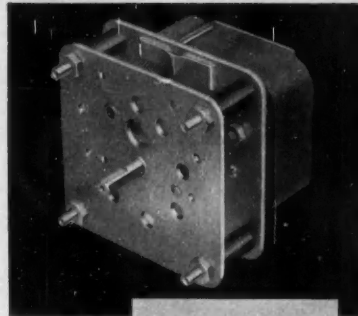
*Which of these Barber-Colman
high-quality, low-cost motors
are needed for your applications
... unidirectional, reversible,
synchronous, or geared?*



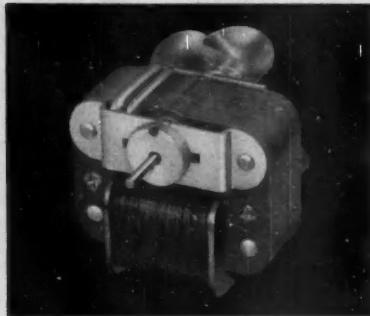
Unidirectional



Reversible



Geared



Synchronous

THE MARK OF QUALITY



a-c small motors

For longest life and finer service per dollar invested, put Barber-Colman motors into your products. High-quality construction throughout eliminates bothersome, costly maintenance... adds to your reputation as a builder of quality equipment. Various types and models for use in appliances, vending machines, projection equipment, office machines, toys, servo-mechanisms, remote switching and positioning, recording instruments, and similar applications. And your cost for these precision-made motors is surprisingly low.

WRITE FOR NEW QUICK REFERENCE FILE on the complete line of Barber-Colman a-c small motors: Unidirectional, reversible, synchronous. Up to 1/20 hp. With or without reduction gearing... open or enclosed types. Stator and rotor sets also available. Free engineering service.

LOW COST

HIGH STARTING TORQUE

QUIET OPERATION

LONG-LIFE LUBRICATION

POROUS BRONZE OR BALL BEARINGS

PRECISION-HOBBED GEARS

QUALITY GUARANTEED

BARBER-COLMAN COMPANY

Dept. 1, 1248 Rock Street, Rockford, Illinois

38 CIRCLE 38 ON READER SERVICE CARD

WHAT'S NEW

pellant was mixed a ton at a time, enough to make a disastrous explosion a possibility so that mixing buildings had to be widely separated from other facilities.

At the present time, the Navy is still unwilling to accept the results of on-stream analyzers so Aerojet's monitored system is not sufficient to "prove" propellants prior to casting in rocket engines. Instead, the Navy requires that the propellant be analyzed positively and even tested by burning at various stages of the production. But Aerojet feels the increased productivity of better material justifies the new line, even with the added inspection required by Navy specifications. Aerojet feels so pleased with the system they are considering developing a full closed-loop control for the process.

—Donald S. Winston
McGraw-Hill News

WESCON: West Coast Vies for Electronics Lead

LOS ANGELES—

On the West Coast, staunchly loyal residents have propounded loud and long that the U.S.'s electronic center is in the far west. Last month's Western Electronic Show and Conference was the strongest evidence yet that the western propounders may be right. Into Los Angeles' new Sports Arena and an adjacent overflow circus tent, a record number of 42,000 visitors trudged, looking at 987 exhibits, another record number (and convention managers claimed they turned away another 200 exhibits because of lack of space).

That kind of attendance makes WESCON stack up favorably even with the giant IRE annual show and meeting held in New York every March. Last year about 55,000 attended the New York show which had somewhere near 900 exhibits.

In some respects the giant show was almost too big. It suffered somewhat from a lack of organization. Exhibits seemed thoroughly mixed in kind and species, so that an engineer pounding the concrete never knew what he might come upon next. Of particular interest to a control engineer were such exhibits as these:

► Five different molecular electronic devices (one-piece semiconductor systems) offered by Westinghouse Electric Corp. for engineering evaluation at \$300 to \$400 a piece (CtE, March '60, p. 35). Included

CONTROL ENGINEERING

were a three-stage amplifier and a complete multivibrator.

► A new oscilloscope that displays a single cycle of a 1,000-Mc sine wave perfectly on a standard 5-in. cathode ray tube by using signal sampling techniques. Built by Hewlett-Packard, the scope uses a 100-kc sampling rate to mark a point in every 10,000th cycle of the signal on each sweep.

► A new scan converter tube, built by Raytheon, was displayed in spectacular surroundings. Raytheon put on a live air traffic display by pulling in data from the Federal Aviation Agency's Air Route Traffic Control Center at Los Angeles. The signal on display originated from FAA radar at Paso Robles, 160 miles northwest of LA, was carried on FAA microwave into the ARTCC where Raytheon scan conversion equipment produced the TV-type signal. Then a Raytheon microwave setup beamed the signal 25 miles to Pasadena's Mt. Wilson, relayed it 18 miles to North Hollywood where Pacific Telephone and Telegraph Co. picked it up and brought it to the Sports Arena via coaxial cable—a prodigious effort for a convention display.

• **At the sessions**—In the heavy session schedule, man-machine relationships drew strong emphasis for control engineers. Among other presentations of interest to control engineers:

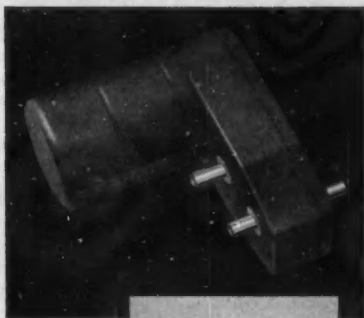
► "Digital Control Techniques for Space", by L. F. Jones and P. Margolin of Westinghouse Air Arm Div. An excellent comparison, including nine tabulations of the size, weight, and power required by the major units of digital computers, by computer memories and arithmetic control units, by circuitry types, and by input-output equipment characteristics. The comparisons will be useful to almost anyone interested in digital computers and techniques.

► "PCM System Trends", by R. L. Sink of Datalab Div. of Consolidated Electrodynamics Corp. An analysis of the characteristics of presently used PCM systems yields the "most probable" system needed for the future. The most probable system design surprisingly can compete favorably with other systems of lesser capacity on virtually all points of comparison.

Among the equipment-describing papers: two described the mechanical and electrical characteristics of the new CM-100 instrumentation tape recorder from Mincom Div. of Minnesota Mining and Mfg. It can record and reproduce 1 Mc at 120 ips and 62.5 kc at 7½ ips. Another paper discussed a "touch detector" by Texas Research Associates Corp. based on the solion electrochemical transducer.

—Edward J. Kompass

Precision permanent magnet reversible motors...gearheads, blowers, and right-angle drives...for airborne and industrial applications



THE MARK OF QUALITY



VOLTAGES FROM 6 V d-c TO 115 V d-c

WITHSTAND AIRCRAFT AND MISSILE AMBIENTS

STABILIZED MAGNETS...UNDAMAGED BY INSTANTANEOUS REVERSALS

SMOOTH RUNNING...LOW COGGING AND RIPPLE

d-c small motors

Barber-Colman offers a large selection of compact, high-quality d-c motors with outputs up to 1/10 hp. Compact design . . . 1¼" to 1½" diameters. Various mountings and speeds . . . several sizes and styles of gearheads and blowers. Integral radio noise filters, magnetic brakes, and governors available for most basic designs. Right-angle drives and multiple-shaft outputs also available for special applications.

WRITE FOR NEW QUICK REFERENCE FILE on the complete line of Barber-Colman electrical components. Includes detailed specifications on a-c and d-c motors, tach generators, blowers, gearheads, relays.

BARBER-COLMAN COMPANY

Dept. J, 1848 Rock Street, Rockford, Illinois



**HOW
MANY
TIMES
HAVE
YOU
FELT
LIKE
THIS
?**

Possibly once too often? If this be true, USC offers a not so unique, but sadly neglected remedy for Hook-itis ... the very basic therapy of giving your control problems to an experienced, dependable instrumentation firm, namely USC!

We are sure that as specialists you are constantly striving for the best ... and we are prepared to give it to you ... the best in design ... the best in fabrication and the best in service. Whether working from your blueprints or designing from performance specifications you can be sure of a guaranteed instrumentation job of the highest quality and performance! ... all engineered and assembled under one roof. Ease the burden of dealing with a dozen separate vendors on every panel job ... USC performs your coordination for you, and acts as your single responsible source!

Write, call or send blueprints to USC for a quote on that next panel ... no obligation, of course.

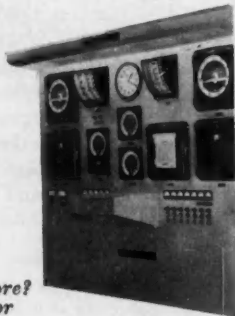
**MAY
WE
GET
YOU
OFF
THE
HOOK
?**

*Want to see more?
Call or write for
case histories.*



U. S. CONTROLS, INC.

410 Fourth Avenue
Brooklyn, New York



Model of automatic supermarket as envisioned by Solartron-John Brown. Display area is at left of first floor, cash desks and delivery area at right. Automatic warehousing operation is on second floor of this configuration.

Buying card for automatic supermarket. Each time card is inserted in slot below desired product, a printer writes out product identification and price in alphanumeric code and dot code. Sides are clipped (shown shaded) so that card is inserted deeper after each item.

Shopping by Card in Automatic Supermarkets

Traditional supermarket shopping—with the shopper picking up items, carrying them around the store in a wheeled cart, and then waiting in a long checkout line—is in for a radical change if engineers at Solartron-John Brown Automation Ltd. can sell store operators a new concept in marketing. Combining data processing techniques with automatic warehousing, SJB offers an automatic supermarket.

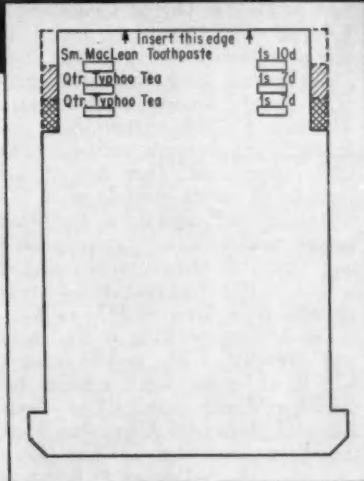
For the shopper the new concept means faster service, with the goods collected simultaneously automatically 15 sec after she has paid for them. For the store operators, it means a 50 percent reduction in floor space, an estimated slash in operating expense amounting to 4 percent of annual sales, and practically an end to losses from pilferage.

SJB's automatic supermarket is divided into three major areas: a shopping or display area in which all the

items carried by the store are exhibited, a line of cash desks at which the shopper can convert a cardful of desired items into goods and pay for them and an automatic warehouse operated by the shopper's card.

Here is how it would work. When the shopper enters the market, she picks up one or more blank buying cards. As the customer saunters through the display area, if she sees an item she wants, she places the card in a slot beneath the desired product. Inside the slot a printer stamps the identification of the product and price both in alphanumeric form and in dot code and clips a bit off each edge of the card so that the next insertion of the card will go deeper (see drawing). More than one of a product is ordered by repeated insertions of the card.

Having completed her "shopping", the customer then turns her card over



Transitron

introduces

an exciting new device for simpler, more reliable, more economical switching circuitry

BINISTOR

(BY-NIS-TOR)

The Silicon NPN Tetraode binistor is a new component and a new concept for the circuit designer!

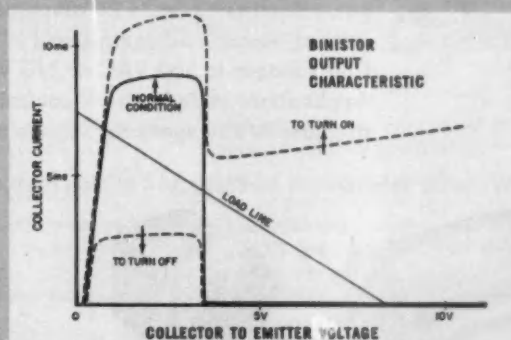
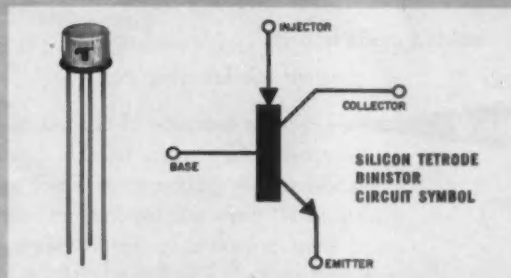
The key parameters of this bi-stable, negative resistance device are determined by external circuitry in contrast to existing devices. The significant reduction of peripheral circuitry results in outstanding savings in cost, space, weight and solder connections. For example, a typical flip-flop requires at least 13 components versus only 4 in an equivalent binistor stage. Very large current and voltage gains are realized in both on and off directions. Inputs and output are compatible in level with typical transistor and diode circuits. The tetraode binistor can operate from -80°C to $+200^{\circ}\text{C}$.

To learn more of this important new development — THE BINISTOR — and how it works — write for Bulletin No. TE-1360.

CIRCLE 41 ON READER SERVICE CARD

CONDENSED SPECIFICATIONS TRANSITRON BINISTOR

Typical Turn-off Current Gain	50 @ 15ma Collector Current
Operating Collector Current Range	50 μa to 15ma
I_j critical	0.5ma @ 5ma Collector Current
Operating Temperature Range without Temperature Compensation	-65°C to 150°C



Transitron



electronic corporation

wakefield, melrose, boston, mass.

SALES OFFICES IN PRINCIPAL CITIES THROUGHOUT THE U.S.A. AND EUROPE • CABLE ADDRESS: TRELCO

Everything Under Control

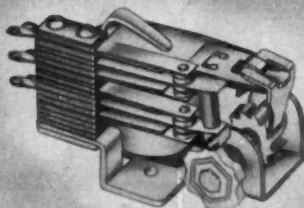


GUARDIAN[®] IMPULSE RELAY

featuring
**SERIES
670**

LONGER LIFE

REDUCED COSTS



GREATER EFFICIENCY

bronze
driving pawl
and stop

flat phosphor bronze
return spring

molded nylon bobbin

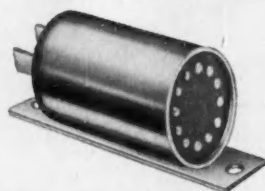
nylon ratchet and cam

positive non-jamming stop

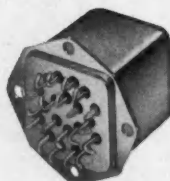
NEW

unique features of Guardian's Series 670 Impulse Relay insure trouble free operation well in excess of one million steps. Each momentary impulse (up to 10 steps per second) causes relay to reverse its cam actuated contacts. Contact arrangements up to D.P.D.T. and ratings to 1500 watts non-inductive, or up to 20 amperes locked motor current, motor load control on 115 volts, 60 cycles. Coil voltages to 230 VAC or 110 VDC. Applications include on/off control of lights, motors, appliances and speakers, among others.

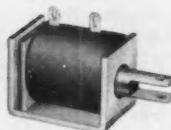
Write for information on these and other Guardian Controls



Rotomite
Continuous Duty Stepper



Series 2505 6 P.D.T.
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No. 24 A.C.
Midget Solenoid

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1558-L W. CARROLL AVENUE, CHICAGO 7, ILLINOIS

WHAT'S NEW

to a clerk at the cash desk who inserts it into an automatic reader which scans the dot code and converts it to signals stored on a magnetic drum. A computer then calculates the total cost of the bill, after comparing the coded prices with standard prices also stored in the memory (this prevents an unscrupulous customer from manipulating the printers in the display area to change prices).

As soon as the order is paid for, the cashier actuates a button that allows the order information stored on the drum to program an automatic warehouse operation. While the customer walks to one of six delivery chutes a short distance from the cash desks, her order is automatically filled.

The automatic warehousing machine selected by SJB is the one built by Industrial Electronic Engineers (CtE, March '58, page 20). Items are stacked in bays that run at right angles to collector conveyors. A special purpose computer receives the order information and then transmits electrical signals to operate relays that energize solenoids to release the proper number of desired items. The released item drops on a conveyor which carries it to the collector conveyor designated by the computer.

SJB estimates that an automatic supermarket could be built for about \$375,000. The automatic reader and computer-programmer would cost about \$60,000; delivery conveyors about \$30,000 apiece installed; and merchandise chutes would run about \$75 per item (a supermarket would have at least 3,000 items; some U.S. markets carry up to 9,000 items).

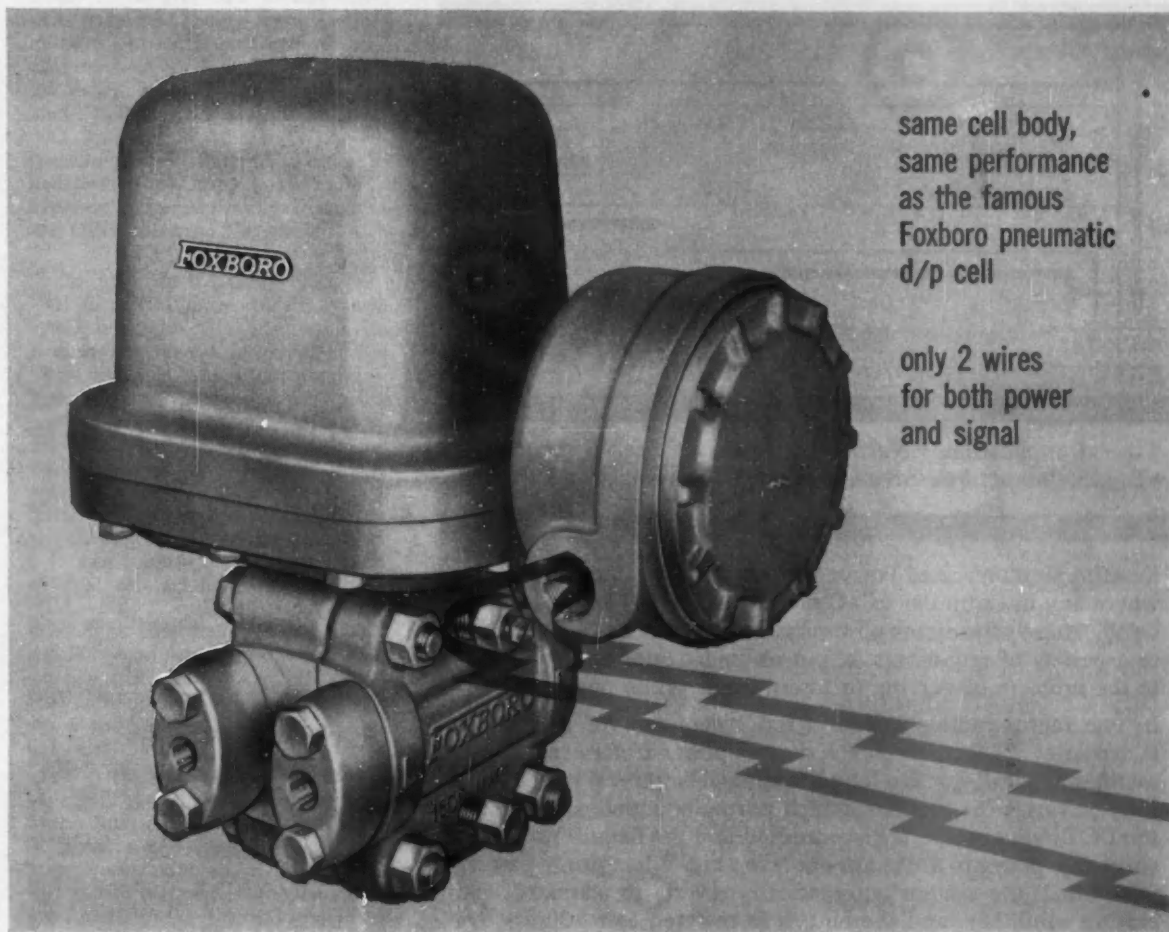
The English company has not yet sold an automatic supermarket. Marketing men are curious to know what effect automation might have on the shopper. Although SJB claims their display area encourages impulse buying, some doubts still exist. Supermarket operators know that large displays have a tendency to boost sales of the product displayed. What will happen to volume, they wonder, when all displays are limited to a single item?

—Derek Barlow

U. S. Control Firms Sign Pacts With Foreign Companies

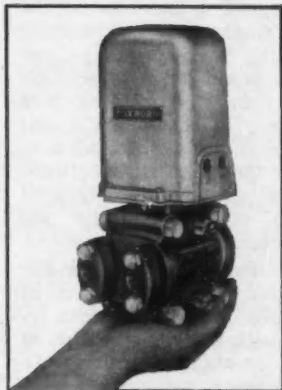
Control companies seem to be working out their own formula for foreign investment (see p. 46). The pattern is to establish a joint-venture agreement with an existing foreign outfit that has already built up a business for

introducing the Foxboro electronic d/p cell* transmitter



same cell body,
same performance
as the famous
Foxboro pneumatic
d/p cell

only 2 wires
for both power
and signal



The Foxboro electronic d/p cell transmitter and this Foxboro pneumatic d/p cell transmitter use the identical cell body. Only the top transmitting mechanism has been changed.

Yes, Foxboro has taken its famous pneumatic d/p Cell and added the benefits of electronic transmission. It's the new Foxboro *electronic* d/p Cell transmitter. Look at the results:

- both power and signal travel over the same pair of unshielded wires — no field power supply required
- pressure, flow, and level transmission up to several miles without lag
- true force-balance design for lowest displacement — highest overrange protection
- high level 10-50 ma d-c signal provides powerful rebalancing force
- adjustable ranges from 5" to 850" water

with external zero adjustment — working pressures of 1500 and 6000 psi

And, of course, you get the same positive overrange protection, the same high sustained accuracy, the same rugged construction that has always been standard with the Foxboro d/p cell transmitter.

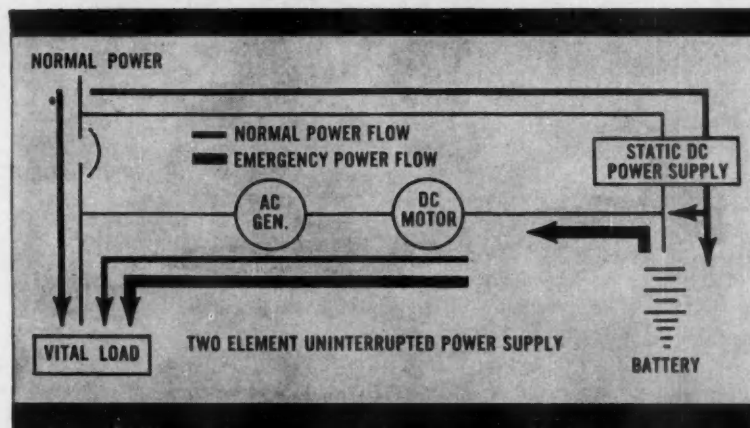
If you're thinking "electronic," it will pay you to investigate this important instrument in the Foxboro Electronic Consotrol* family. Get in touch with your Foxboro Field Engineer for complete details, or write for Bulletin 21-10. The Foxboro Company, 8510 Neponset Avenue, Foxboro, Massachusetts.

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Typical applications: Nuclear Reactors • Power Distribution
• Digital Computers • Process Control • Communication Systems

Kearfott Uninterrupted Power Systems are vital in applications where any interruption in AC power can cause serious loss or delay. These continuous power systems, which can be tailored to a variety of requirements, put an end—once and for all—to the problem of varying or intermittent prime power.

In one representative system arrangement, an AC generator is driven by a DC motor which derives power from a regulated rectifier in parallel with a long-life storage battery. When power fails or varies the rectifier, which normally supplies power to the DC driving motor, is disconnected and the battery provides surge-free power to the motor—in zero time. When prime power is restored, the system automatically reverts to standard operating conditions and the battery is restored to readiness by the main battery charger.

Also available in 2 and 3 unit systems operating in parallel with or isolated from the line, Kearfott's compact uninterrupted power systems also provide audible and/or visual alarms to indicate over- and under-voltage, overload or ground conditions.

*Generator ratings to
150 KVA 60 and 400 cycles,
single and polyphase.*

*Frequency, voltage, and
transfer regulation as
required by the application.*

For complete data on the wide variety of arrangements available, write to:



**KEARFOTT DIVISION
GENERAL PRECISION, INC.**

Little Falls, New Jersey

WHAT'S NEW

itself in its own country.

Last year Daystrom, Inc. made news (CtE, Dec. '59, p. 48) with an agreement with the Japanese firm Nichimen & Co. Ltd. to set up a joint venture called Nichimen KK. The company has rights to Daystrom designed products, and Daystrom may import products made in Japan for sale here. Earlier this year (CtE, Feb. '60, p. 44) Hamilton Standard Div. of United Aircraft Corp. purchased half of Microtecnica, Inc., an Italian firm making navigation instruments. The Italians will produce HSD designed goods.

• **Latin touch**—Another big U. S. firm to make a commitment in Italy on a joint basis is Raytheon Corp. which this spring bought a 40-percent interest in an Italian electronics and radar navigation outfit that was formed in a merger of the Microlambda and Sindel companies. More recent Italian ventures are moves by Fairchild Camera & Instrument Corp. of Syosset, N. Y., to collaborate in a semiconductor firm and by Laboratory for Electronics, Inc. to acquire part of a Florence firm. Fairchild, through its Semiconductor Corp., Palo Alto, Calif., has acquired part of Società Generale Semiconduttori (SGA). SGA's Agrate, Milan, plant will begin producing Fairchild products for the European Common Market before 1961, and Fairchild will sell SGA's semiconductors in the U.S.

LFE's arrangement calls for it to acquire an interest in Segnalemento Marittimo ed Aereo, S.p.A. of Florence. SMA's products (navigation radars and microwave, infrared, lighting, and signaling equipment) complement LFE's navigation systems.

Also designed to move in on the Common Market is the recently formed (CtE, Aug. '60, p. 6) Compagnie Europeene d'Autotisme Electronique in Paris. The outfit is a joint venture of Thompson Ramo Wooldridge, Inc. of Los Angeles with Compagnie Generale de Telegraphic sans Fil and Inter technique both of France to manufacture and sell TRW's process control computers.

• **Oriental flavor**—On the other side of the world, Litton Industries of Beverly Hills has entered into an agreement with Kobe Kogyo Corp. in Japan that establishes a working relationship between the companies in the microwave and electron tube fields. It's the first Japanese manufacturing arrangement for Litton. Kobe Kogyo has tripled sales since 1956; 1959 sales; more than \$17 million.

**WHERE
DO YOU
STAND ON
COMPUTER CONTROL—
LEADING OR LAGGING?**



Far-sighted leaders in industry are realizing the benefits made possible by applying computer control systems to their processes.

Working with these leaders, General Electric has already pioneered the application of twenty on-line GE-312 computer systems now being implemented in these basic areas—STEEL, ELECTRIC UTILITIES, CHEMICAL, CEMENT, and PRODUCTION CONTROL for various manufacturing applications.

The GE-312 Computer Control System embodies adaptability and flexibility to meet many types of applications in varying size plants. For example, compare its expandable memory—capacity up to 52,000 words. Compare its flexible input/output—capable of scanning up to 1500 instrument inputs. These are maximum capabilities, expandable from a minimum system. You buy a system tailored to your exact requirements.

Add to this versatile equipment the computer systems engineering ability demonstrated by General Electric in implementing these twenty GE-312 system applications.

Add also the long history of General Electric overall systems know-how—its broad background in the equipment, processes and materials to which you apply computer control.

Tomorrow's profits will come from today's combination of vision, equipment, and know-how. *Where do you stand?*

There are General Electric Sales and Application engineers in over one hundred offices throughout the nation to serve you. *Phone* the nearest General Electric Apparatus Sales Office, or *wire* General Electric Computer Department, 13438 North Black Canyon Highway, Phoenix, Arizona.

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CFA-50 (9-60)

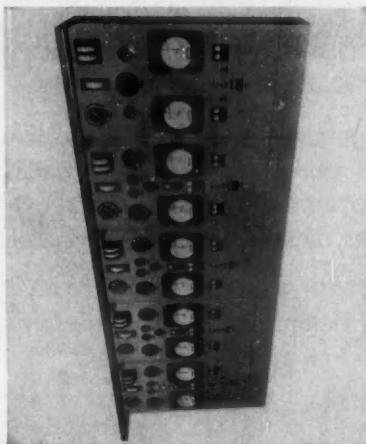
General Electric—a pioneer in computer systems for all phases of business, industrial, scientific, engineering, and financial endeavor.

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**Judging by
the Company
We Keep...**

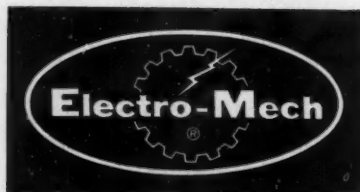
Electro-Mech

... "The Company We Keep" undoubtedly all agree that: **YOU DON'T HAVE TO STAND ON YOUR HEAD TO RECOGNIZE GOOD WORKMANSHIP!**



If you are standing squarely on your feet and looking for a Control System manufacturing-specialist with an intimate knowledge of Industry's demands — from Power Plants to Refineries — from Steel Mills to Chemical Plants we suggest you join "the Company We Keep" and request a quotation from Electro-Mech on that planned plant automation job you are working on.

Electro-Mech Corp., Norwood, N. J.



A Look At Control Abroad

McGraw-Hill foreign investment survey adds weight to news of joint ventures (see p. 42) to paint bright picture of control overseas. IBM's pact highlights Japanese scene.

Investment Peak Sets Stage For Control Sales Abroad

American industrial companies plan to spend 15 percent more abroad in 1960 on plants, equipment, and property than they did last year. Concerns cooperating in the second survey by McGraw-Hill's Economic Services have plans to invest \$2.4 billion in foreign countries—meaning big opportunities for instrument and control sales. What's more, cooperating companies already have plans to top this—by another 6 percent—in 1961.

While these figures represent the plans of only those companies in the survey—and reflect their thinking as of August—the firms surveyed account for about three-fourths of capital expenditures overseas by all U. S. manufacturing and petroleum companies.

• **Dollars in ECM**—Manufacturers are pouring their biggest budgets into Common Market countries. They indicated that 17 percent of their overseas expenditures in 1959 were in these countries, and they plan to up this to 24 percent this year and to 27 percent in 1961. In addition, Europe as a whole will account for fully half of all foreign outlays by American manufacturers in 1961. Biggest shift is planned by chemical firms: only 8 percent of '59 dollars went to ECM states; this will be increased to 22 percent this year, 32 percent next.

Manufacturers are probably headed for a record year with planned expenditures pitched to hit well over \$1 billion. The last previous peak is believed to have been in 1957 at \$929 million. Machinery companies are the biggest spenders with 1960 overseas budget pegged at \$351.1 million, up a whopping 41 percent over '59. And these companies are set to boost this figure to \$410.8 in 1961.

Other industry groups predicting increases over last year of 20 percent or more include companies producing transportation equipment, chemicals, stone, clay and glass, food and beverages, and miscellaneous products (including textiles). Only primary metal producers and the fabricated metals

and instruments group indicate plans decreased from last year. The latter group estimates a figure off last year's \$31.7 million by 19 percent but forecasts an increase in 1961 to \$34.7 million. (But for a possible reason for lower capital expenditures needed by instrument and control makers—the joint venture approach—see p. 42).

• **Controls market**—By far the greater portion of planned overseas investment is scheduled for new production facilities—with their necessary instrument and control applications. Only 12 percent will be used to purchase land and existing facilities this year. Even a larger proportion will go for new facilities next year.

Other overseas figures investigated by the publishing company survey were exports and sales of foreign subsidiaries of U. S. firms. Total export sales are expected to rise to \$13.2 billion this year, an increase of 11 percent over 1959. (Manufacturing companies told McGraw-Hill last spring they expected only an 8-percent increase in domestic sales.) These figures represent sales by all manufacturers and petroleum companies—unlike the capital investment data; U. S. Dept. of Commerce figures were used to expand the reports.

Sales of foreign subsidiaries of manufacturers are expected to rise 11 percent this year, and by 1961 they may surpass export sales from this country. The industry group that includes instrument companies expects an 8-percent increase in sales of foreign subsidiaries and 11 percent more in 1961. But export sales by this group should be off 2 percent in 1960 to \$644.2 million. An increase to \$676.4 million is expected in 1961.

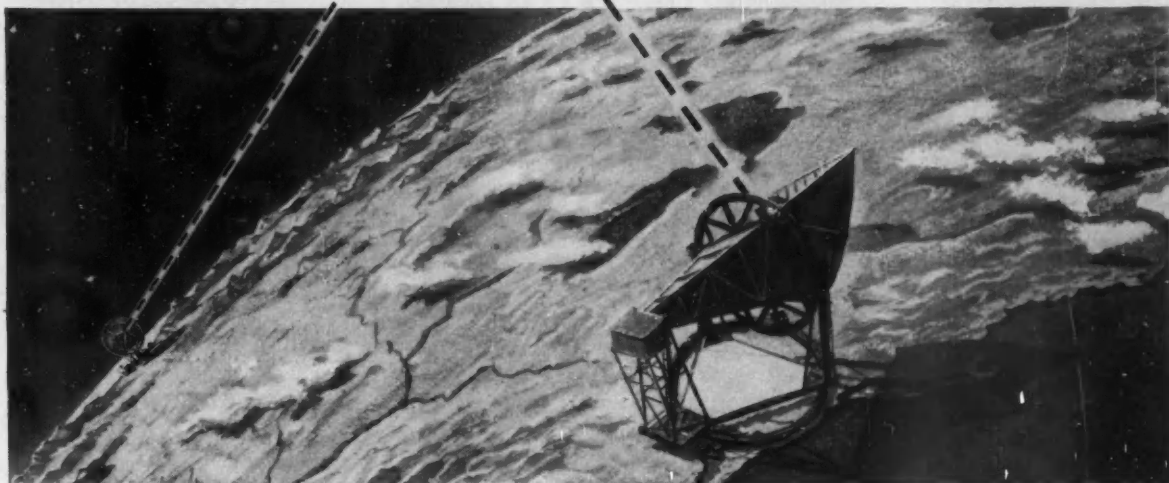
IBM Sets Computer Licenses for Japan

TOKYO—

After four years of haggling, International Business Machines Corp. has reached an agreement in principle with Japan's Ministry of International Trade and Industry to set up a new manufacturing subsidiary here.

FIRST PHONE CALL VIA MAN-MADE SATELLITE!

"Project Echo" satellite went into a near-perfect circular orbit 1000 miles high, circling the earth once every two hours. Its orbital path covered all parts of the U. S.



BELL TELEPHONE LABORATORIES BOUNCES VOICE OFF SPHERE PLACED IN ORBIT A THOUSAND MILES ABOVE THE EARTH

Think of watching a royal wedding in Europe by live TV, or telephoning to Singapore or Calcutta—*by way of outer-space satellites!* A mere dream a few years ago, this idea is now a giant step closer to reality.

Bell Telephone Laboratories recently took the step by successfully bouncing a phone call between its Holmdel, N. J., test site and the Jet Propulsion Laboratory of the National Aeronautics and Space Administration (NASA) in Goldstone, California. The reflector was a 100-foot sphere of aluminized plastic orbiting the earth 1000 miles up.

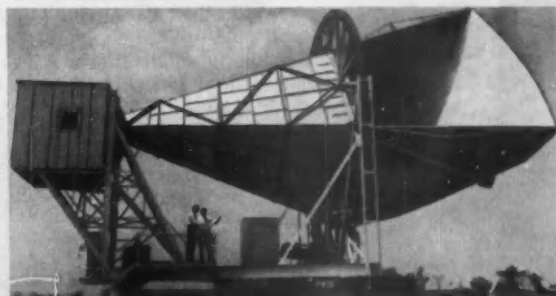
Dramatic application of telephone science

Sponsored by NASA, this dramatic experiment—known as "Project Echo"—relied heavily on telephone science for its fulfillment...

- The Delta rocket which carried the satellite into space was steered into a precise orbit by the Bell Laboratories Command Guidance System. This is the same system which recently guided the remarkable Tiros I weather satellite into its near-perfect circular orbit.
- To pick up the signals, a special horn-reflector antenna was used. Previously perfected by Bell Laboratories for microwave radio relay, it is virtually immune to common radio "noise" interference. The amplifier—also a Laboratories development—was a traveling wave "maser" with very low noise susceptibility. The signals were still further protected from noise by a special FM receiving technique invented at Bell Laboratories.

"Project Echo" foreshadows the day when numerous man-made satellites might be in orbit all around the earth, acting as 24-hour-a-day relay stations for TV programs and phone calls between all nations.

This experiment shows how Bell Laboratories, as part of the Bell System, is working to advance space communication. Just as we pioneered in world-wide telephone service by radio and cable, so we are pioneering now in using outer space to improve communications on earth. It's part of our job, and we are a long way toward the goal.



Giant ultra-sensitive horn-reflector antenna which received signals bounced off the satellite. It is located at Bell Telephone Laboratories, Holmdel, New Jersey.



BELL TELEPHONE LABORATORIES
WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT



TOMORROW'S CONTROL DEVICE AVAILABLE NOW!

Optimum design for practically any power control application from watts to kilowatts! Miniature, all-semiconductor SCR servo amplifiers* developed by General Electronic Control, Inc. now make it possible!

Thousands of different control amplifiers for applications requiring rapid, precise proportionate control! Individual circuit modules are light, small and easy to combine. New Silicon Controlled Rectifiers (SCR's) make units versatile, efficient.

Modules meet military shock, vibration and environmental requirements—are particularly suited for use in ground support equipment, rockets, missiles, telemetry and other 400 cycle applications requiring high reliability.

Typical 60 cycle industrial applications: AC and DC motor controls, light and brightness controls, temperature controls, welding equipment and power supplies.

For Bulletin 6069 giving advance technical information write, wire or phone to G.E.C., Application Engineering Department.

Patents Pending

GENERAL ELECTRONIC CONTROL, INC.

9001 Bloomington Freeway • Minneapolis 20, Minnesota • TUXedo 8-5511

WHAT'S NEW

Terms of the agreement call for IBM to receive guaranteed remittable royalties on IBM-Japan's sales and for IBM to license (with royalties) Japanese firms to produce IBM-designed components and systems.

Roadblock in the negotiations up until August was IBM's insistence on majority ownership of its subsidiary and MITI's traditional opposition to subsidiaries that are more than 50 percent foreign owned. In addition, the Japanese government has tried to form a cartel within its electronic industry to develop computers and wanted IBM to contribute its know-how.

• **The compromise**—MITI has relented on its ownership demands and IBM, in turn, has agreed to a technical assistance program. As worked out by MITI and J. W. Berkenstock, IBM's vice-president for commercial development, IBM will own 99 percent of the new IBM-Japan. In return, IBM will license Japanese companies as subcontractors to build complete machines and systems (under 5-percent royalty) and computer components (at 1-percent royalties).

IBM will also receive a 10-percent royalty on sales of its subsidiary, and remission of the profits to the U.S. is guaranteed. All royalty payments are to last five years.

The pact still must be worked out in detail and be approved by the Foreign Investment Council.

• **Gentleman's agreement**—According to Japanese sources, IBM and MITI will enter into a "gentleman's agreement" as to what classes of computers will be built in Japan and the extent of technical assistance IBM will provide.

Companies expected to take licenses include Fuji Tsushinki, Nippon-Electric, Oki Electric, among others.

• **Made in Japan**—Board Chairman Komishushina of the present IBM-Japan has stated that the company is planning to export components for IBM machines to the U.S. On the other hand, equipment built in Japan would contain some components imported from the U.S.

Japanese electronics industry sources see the IBM deal as the long-awaited breakthrough into the electronic computer field that has been held up until now by a lack of technical knowledge.

MITI sources have insisted that the IBM agreement will not set a precedent; the Japanese government will still hold out for Japanese majority or 50-percent ownership of any new foreign manufacturing subsidiary.

1 Look up

Every time another American missile is fired, special new cables are put to the toughest test of all.

These cables *must* perform. If they failed there'd be no telemetering, data recording, circuit checks, electronic computing, etc.

To create such cables, you need special research and engineering

skills, special experience, and a *hard-headed stubbornness about quality.*

That's why you find so many millions of feet of these specially designed instrumentation cables bear the label, "Rome Cable division of Alcoa."

Two places to look next time you need a cable that never existed before

Look down.

Learn the capabilities of your cable maker, the types of insulations available, the standards to which his cables are built. Look over some typical cables—from 2 to 193 conductors in each—to get an idea of what he can do for you.

Arm yourself with a copy of our

Bulletin RCD-400, "Instrumentation Cables". It even contains a "Cable Procurement Information Form," on which you can outline your needs.

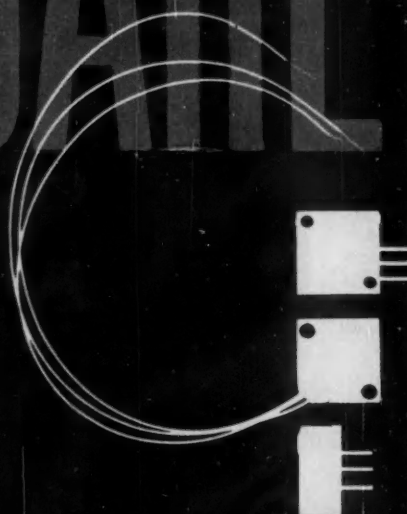
No obligation, of course. Just write for a copy. Department 10-100, Rome, New York.

ROME CABLE
DIVISION OF **ALCOA**

2 Look down



SQUARETRIM



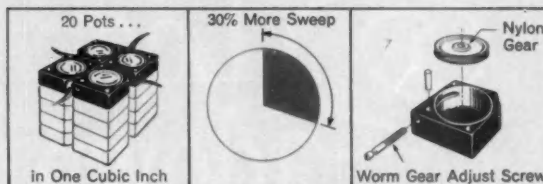
FIVE YEARS OF PROVEN TRIMMER PERFORMANCE

THE ONLY SQUARE SUBMINIATURE POT WITH 1,750,000 FIELD-PROVEN APPLICATIONS

FOR BETTER STACKING...up to 20 SQUARETRIMS in one cubic inch.

FOR MORE ACCURATE TRIMMING...30% more resistance turns plus 45:1 adjustment ratio gives more precise trimming than conventional designs.

FOR MECHANICAL AND THERMAL STABILITY...worm gear adjusting device helps assure rugged mechanical stability, and unique circular mandrel eliminates expansion-contraction effects for thermal stability.



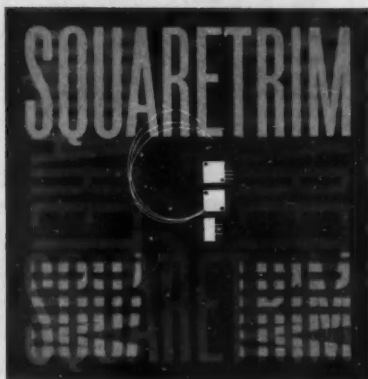
For full specifications on the complete SQUARETRIM line, contact your Daystrom representative or write for Data File CE-112-3.

DAYSTROM, INCORPORATED

PACIFIC DIVISION

9320 Lincoln Boulevard, Los Angeles 45, Calif.

CIRCLE 50 ON READER SERVICE CARD



MAXIMUM RESISTANCE in the SMALLEST HEIGHT OFF BOARD POT AVAILABLE



MODEL 312 (ACTUAL SIZE)

The Daystrom Series 312 subminiature trimming potentiometers are ideal for stacking printed circuit boards into modular assemblies. By combining a height off board (or extension) of only .195 inches with resistance values up to 100 k, you save space without sacrificing performance.

What's more, the 312 Series provides excellent resolution from longer, more precise windings...environmental stability through an exclusive wiper locking technique...and higher power ratings from -55° to $+150^{\circ}\text{C}$.

With these features you get the reliability assurance of dealing with the originator of square-shaped trimmers—Daystrom—with 5 years and well over 1,750,000 field-proven SQUARETRIMs behind them.

For full information on standard model 312 trimmers—and specially treated models that meet the most severe humidity specifications—contact your Daystrom Potentiometer Representative or Distributor. Or write for Data File CE-1178-1.

DAYSTROM
PACIFIC DIVISION
9320 LINCOLN BOULEVARD
LOS ANGELES 45, CALIF.

IMPORTANT MOVES BY KEY PEOPLE

Reichel Assumes Corporate Counsel Post at UAC

Waldimir Reichel, who has been chief of basic design for the Norden Div. of United Aircraft Corp., has been appointed engineering counsel to all divisions of the corporation. He was also engineering manager of Norden's Ketay Dept.

Reichel has been a pioneer in instrument miniaturization and has extensive experience in fields of interest to UAC's Pratt & Whitney Aircraft, Hamilton Standard, and Sikorsky Aircraft divisions.



Bibby Succeeds Herman As Rem Rand President



New president of the Remington Rand Div. of Sperry Rand Corp. is Dause L. Bibby, who has succeeded Kenneth R. Herman in that position. Herman

will remain executive vice-president, a post he has held concurrently.

Bibby joined Rem Rand as its executive vice-president in March 1959 from a position as executive v-p and a director of Daystrom, Inc., a position he held for three years. Prior to that he was vice-president of IBM.

Herman has been with Sperry Rand and its predecessor companies for 29 years. He was president of the Vickers, Inc. Div. before moving to corporate headquarters in New York.

Crosley Executive Joins Aeronutronic Division

James C. Elms, former executive vice-president of the Crosley Div. of Avco Corp., is now general operations manager of Electronic Systems Operations at the Aeronutronic Div. of Ford Motor Co. in Newport Beach, Calif. Elms replaces Dr. Ernst H. Krause, now director of the Ford unit's technical staff.

Elms originally joined Avco-Crosley in April 1959 as vice-president, elec-



tronic systems and was named to his last post early this year. Prior to joining Avco he was with the Martin Co.'s Denver Div. as manager of its Avionics Dept., where he was responsible for certain electronic systems for the Titan missile.

The Electronic Systems group provides technical support for missile and satellite range programs. For example, the organization is responsible, under Navy contract, for instrumentation planning for the Pacific Missile Range.

Beckman Names Baumann Manager for Systems Div.



Robert J. Baumann has been appointed manager of the Systems Div. of Beckman Instruments, Inc., in Anaheim, Calif. He has been acting manager of

the unit since last December when he joined the division from the company's corporate marketing staff.

Prior to joining Beckman, Baumann was industrial marketing manager for a division of General Mills and held positions with GE and Standard Oil of Indiana.

Other Important Moves

Arthur R. Teasdale, Jr., an authority on missile guidance has joined the Martin Co. in Baltimore, Md., as a technical consultant. He comes to Martin from a position as manager of the Electronics Div. of Temco Electronics and Missiles Co. in Dallas.

Dr. Gordon J. Murphy has been promoted to full professor and chairman of the Electrical Engineering Dept. at Northwestern University's Technological Institute, Evanston, Ill. Dr. Murphy has helped make control systems engineering the most active field in E.E. at Northwestern. About half of the graduate students in the department are studying it.

Dr. W. Wai Chao is the newly appointed director of research and development at Vickers, Inc., Div. of Sperry Rand Corp. Dr. Chao joined the Detroit firm last year as director of research after directing such projects as rocket engine development for the Discoverer project and altitude control systems for Project Mercury and the X-15.

(More business news on p. 193)

NAME YOUR OSCILLOGRAPHIC RECORDING NEEDS

SANBORN



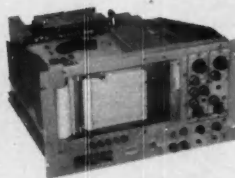
**"BUILDING-BLOCK" FLEXIBILITY
CAN MEET THEM**



1-channel, 21 lb. portables — Model 299 for general purpose DC recording, Model 301 for AC strain gage recording.

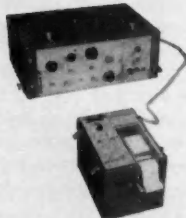


Model 320 2-channel, 4-speed portable . . . 50 mm wide channels.

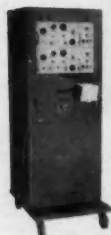


Model 297 2-channel recorder, rack mount in 10 1/2 inch space or portable housing.

1- to 8-channel "150's", DC to 100 cps.



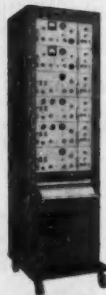
MODEL 151



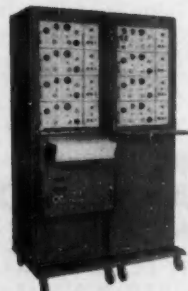
MODEL 152



MODEL 154



MODEL 156



MODEL 158

INPUT
CHARACTERISTICS

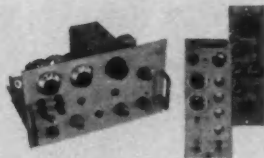
FREQUENCY
RESPONSE RANGE
... RECORDING
METHOD

PACKAGING . . .
NUMBER OF CHANNELS

LARGE-SCREEN
VISUAL PRESENTATION

TRANSDUCERS

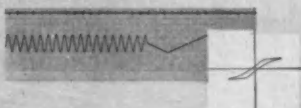
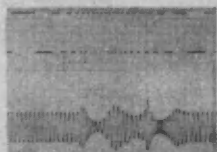
RELATED INSTRUMENTS,
ACCESSORIES



Interchangeable, plug-in preamps for "850" systems include Carrier, Phase-Sensitive Demodulator, DC Coupling, Low Level ... for "350" systems, all "850" types plus 400 Cycle Frequency Deviation, Logarithmic types ... for "150" systems, all "350" and "850" types plus AC-DC, AC Wattmeter, RMS Volt/Ammeter, Frequency Meter, Stabilized DC types, and Triplexer 3-channel electronic switch.



Single-chassis, 6- and 8-channel amplifiers for "950" systems include high and low gain general purpose types ... for "650" systems and optical oscillographs of other manufacturers, a 6- or 8-channel medium gain amplifier.



From DC to 150 cps with most Sanborn systems which produce inkless, heated stylus recordings in true rectangular coordinates ... up to 3000 cps with new optical system using ultraviolet-sensitive paper. Optical X-Y Recorder has 2500"/sec. writing speed, immediate readout.



Sanborn "building block" units give you extremely wide packaging flexibility: "150" amplifiers and recorders can be separately housed or combined in mobile cabinets ... "350" preamps may be used alone or in a system ... "850" and "950" systems can have up to 16 channels in a single cabinet ... optical 3000 cycle recorder can be housed with X-Y recorder, etc. All Sanborn multi-channel recorder assemblies and 350, 650, 850 & 950 amplifier modules fit standard 19" racks.



Up to 8 brilliant, long-persistence traces presented simultaneously on the new 17" Sanborn Model 769 scope. Circuit includes individual gating amplifiers for each Y axis.

SANBORN COMPANY

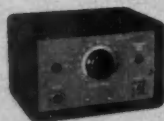
INDUSTRIAL DIVISION



175 Wyman Street, Waltham 54, Mass.



Measure linear velocity and displacement with Sanborn LVsyn, Linear syn and "probe-style" transducers. Strokes from $\pm 0.005"$ to 10", high sensitivities, 0.5% linearity; special types for high temperatures, pressures ... single-ended or differential pressure measurements at 40 $\mu\text{v}/0.1 \text{ mmHg}$ /volt sensitivities, with 267, 268 Series pressure transducers.



Complete Sanborn equipment for your oscillographic recording needs includes a variable speed Chart Viewer ... Servo Monitor Phase Shifter ... "150" Series Wide Band Driver Amplifier ... a Monitor Meter ... 4- to 32-channel Event Recorders with Transistor Driver Amplifiers.



See how Sanborn oscillographic recording building-block flexibility can provide the most suitable equipment for your needs. Ask your Sanborn Sales-Engineering Representative — offices in principal cities throughout the United States, Canada and foreign countries.



Economical 8-channel "950" high gain, general purpose system.



Model 958-16 Complete 16-channel system with amplification ... cabinet or rack mounting.



6- or 8-channel "850's", min. panel space.



Model 650 1- to 24-channel optical system, DC to 5000 cps.



Model 670A High speed (100 cps) optical X-Y recorder.

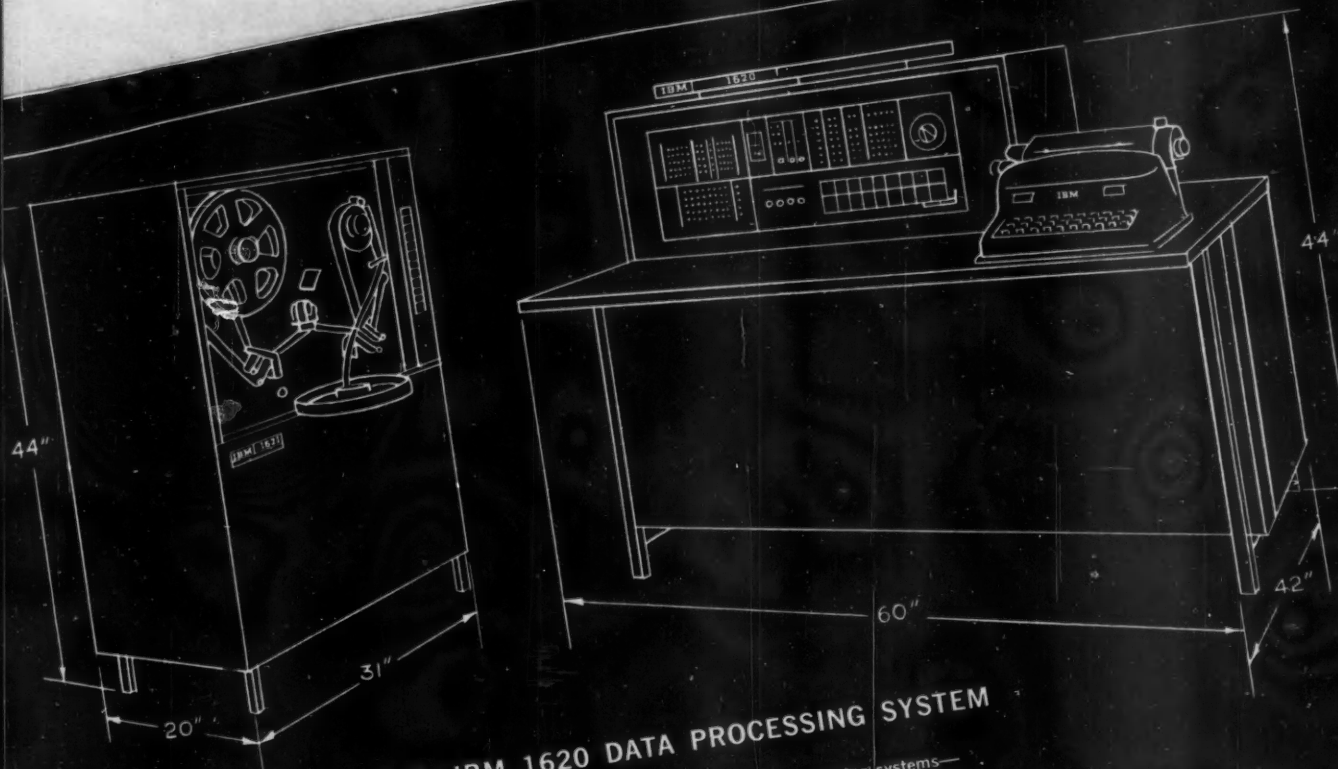


Simplified 6- or 8-channel system, 5 volts full scale.



6- or 8-channel "350's", DC to 150 cps.

CIRCLE 53 ON READER SERVICE CARD



SPECIFICATIONS: IBM 1620 DATA PROCESSING SYSTEM

Core storage—20,000 digits
Automatic operation—stored programming
High computing speed—20 microsecond machine cycle
Powerful instructions with two data addresses
Decimal and alphabetic
Variable field and record length—any size numbers

Advanced programming systems—
Fortran and symbolic programming
Compatibility with other computers through Fortran
Simple console with logging features
Self checking throughout
Transistorized circuitry—
compact, economical, reliable
Paper tape input and output

The 1620 will meet technical computing requirements too complex for the conventional desk-type calculator. It provides many advantages of larger systems at a much lower cost. In addition, it can be used to support other data processing systems such as the IBM 650, 704, 705, 709, 7070 and 7090.

Information enters the system from the typewriter of the 1620 Central Processing Unit, or from the 1621 Paper Tape Reader. Output is to the typewriter or 961 Tape Punch.

Machine	Weight in lbs.	Current Requirements	Power cord	Interconnecting cable	Heat Load Specification BTU/Hr
1620	1,000	20 Amps., 115 Volts, single phase 10 Amps., 230 Volts, single phase 6.5 Amps., 208 Volts, three phase	10' 3-Wire for 115 and 230 Volts 10' 4-Wire for 208 Volts	10' signal 10' power	5,000 2,000
1621	280				



FREE YOUR ENGINEERING STAFF FOR MORE CREATIVE WORK . . .

IBM 1620 LOW-COST, DESK-SIZE COMPUTER **RELIEVES YOUR STAFF OF TIME CONSUMING WORK ...SOLVES WIDE RANGE OF SPECIALIZED PROBLEMS**

Problems that used to tie up your engineering staff for days can now be solved . . . with electronic accuracy . . . in minutes! The IBM 1620 is a low-cost, desk-size engineering computer that solves a tremendous range of routine and specialized engineering problems quickly and easily. The 1620 offers you an economical way to increase staff productivity, helps pave the way for profitable growth.

The 1620 is easy to learn, easy to operate, easy to communicate with. It adapts readily to specialized and general problems such as design development, blending problems involving matrix arithmetic, research calculations with differential equations. It facilitates the development of mathematical models for plant and shop operation, and evaluation studies employing statistical techniques such as regression analysis.

IBM also makes available a comprehensive library of mathematical routines and programs as well as reliable customer engineering. These services supporting the 1620 are an important part of IBM Balanced Data Processing. They make it easy for you to make full use of the 1620 in your operations without delay. Like all IBM data processing equipment, the 1620 may be purchased or leased.

BALANCED DATA PROCESSING



IBM

®

Dept. 805
International Business Machines Corporation
112 East Post Road, White Plains, N. Y.
Please send me further information and complete specifications for
the IBM 1620 Engineering Computer. I am particularly interested in:

(engineering application) _____

NAME _____

POSITION _____

COMPANY _____

ADDRESS _____

CITY _____ ZONE _____ STATE _____

Here's why the NEW AO TRACE-MASTER is the world's finest 8-channel direct writing recorder!

American Optical Company, famous for precision instrumentation for 138 years, introduces an electronic direct-writing recorder of unique design, in which ultra-precise electromechanics has been combined with advanced electronics to achieve truly superior performance.

Finest Writing Method Ever

Unique direct-carbon-transfer writing method. Trace is uniformly black and up to four times thinner than that made by any other recorder. Minute variations in phenomena measured are more faithful, meaningful. Carbon trace cannot fade... may be easily reproduced.

Finest Frequency-Amplitude Performance

TRACE-MASTER'S multiple-feedback wide-range Driver circuitry, combined with the advanced pen-motor design, produces wider frequency response at larger amplitudes than any other recorder. TRACE-MASTER response is flat—within 1%—from dc to 110 cps at 40 mm!

Band Amplitude Product (i.e. Bandwidth times Amplitude) is 5600...140 cps (3 db point) x 40mm!

Finest Chart-Drive Facilities

TRACE-MASTER provides widest chart-speed range...0.1 to 500 mm/sec...of any direct-writing recorder! Convenient

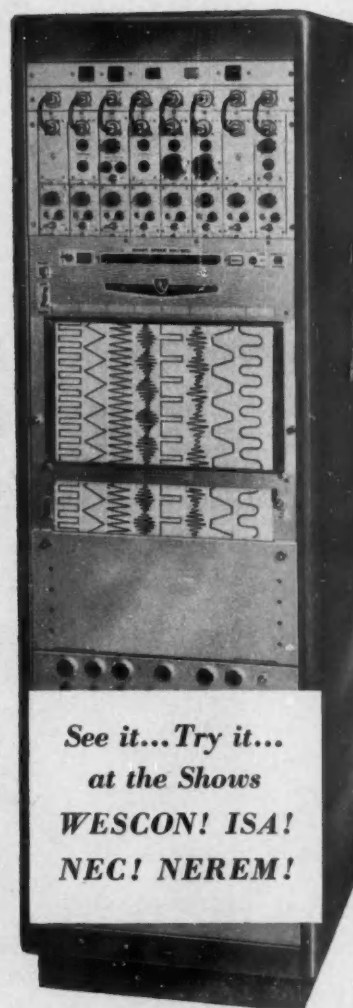
push-button selection. Take-up reel automatically stores full 1000 ft. record. Writing table tilts for easy chart annotations. Guide rails permit quick, easy paper-roll changes. Low cost chart paper makes practical protracted recording at high speeds.

Finest Resolution, Linearity, Stability

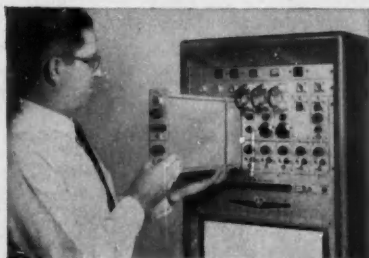
Thin carbon trace (thinner by 4 to 1 over most recorders) and high Band Amplitude Product (higher by 6 to 1 over other recorders) provide up to 24 times the resolving power or ability to detect short, sharp variations in the record. The superior linearity ($\pm 1\%$) and stability in rectilinear presentation permit full use of this unexcelled resolution.

Finest Systems Oriented Compatibility

Fully transistorized circuitry...application of combined dc level and signal multiple feedback...complete interchangeability of modular signal-conditioning elements... are some of the features that make the AO TRACE-MASTER the world's finest 8-channel direct writing recorder.



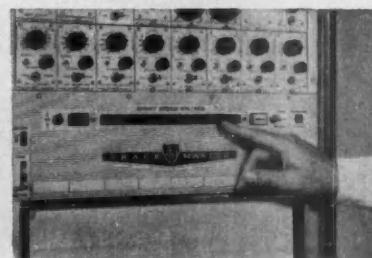
See it...Try it...
at the Shows
WESCON! ISA!
NEC! NEREM!



Entire channel easily accessible and completely interchangeable as single unit.



Platen tilts to convenient writing angle.



Widest range chart speed...push-button selection through 0.1 mm/sec to 500 mm/sec.

**WRITE, WIRE, TELEPHONE TODAY
FOR COMPLETE INFORMATION!**

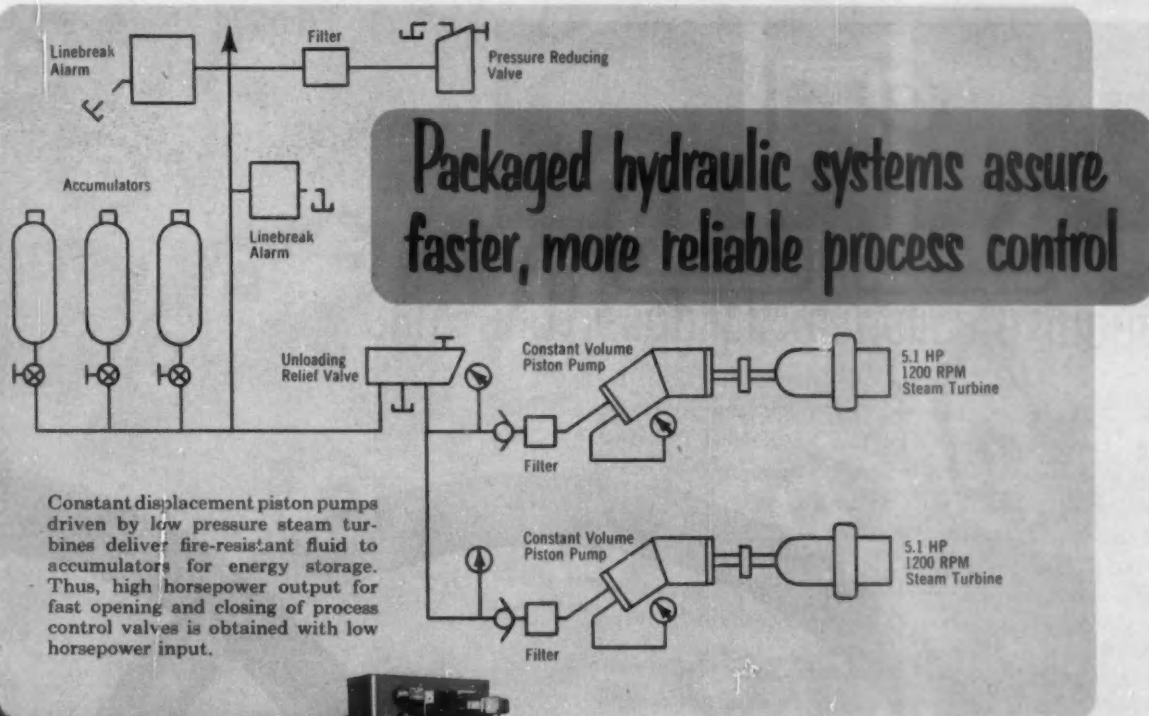
Complete Engineering Bulletins available.
Field Sales Engineers at your service everywhere.

**American  Optical
COMPANY**

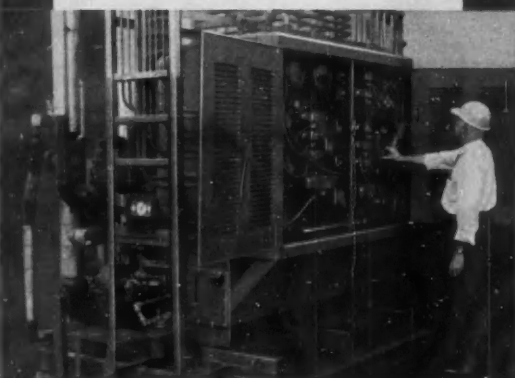
INSTRUMENT DIVISION, BUFFALO 15, NEW YORK

←CIRCLE 55 ON READER SERVICE CARD

CIRCLE 56 ON READER SERVICE CARD



Control console and power unit form electro-hydraulic system for controlling automatic heat treatment cycle. Physical layout provides optimum circuit efficiency, ease of servicing, and good appearance.



This power package includes all hydraulic pumps and valves for complete control of automatic cyclic operation of process in a butadiene plant.

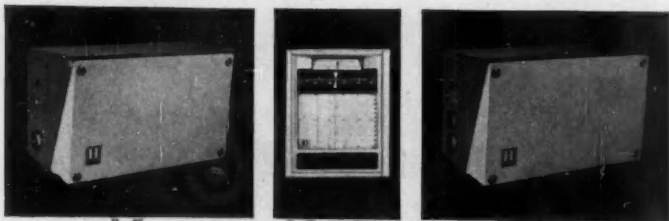
Fast and precisely controlled motions, having the high reliability demanded by modern processing, are inherent characteristics of hydraulics. In addition, these advantages are obtained at low cost, for you can cover your full range of operations—from valve control to power transmission—with standard Vickers components. Your engineers enjoy unlimited design flexibility through a choice of electric, electronic, pneumatic and manual signals to control the hydraulic pumps, motors, cylinders, and variable speed drives.

Vickers complete packaged systems are ready to go into service upon arrival in your plant, since they are thoroughly pretested before shipment. They are properly designed and built to give maximum service life with little downtime, thus helping to keep your plant on stream.

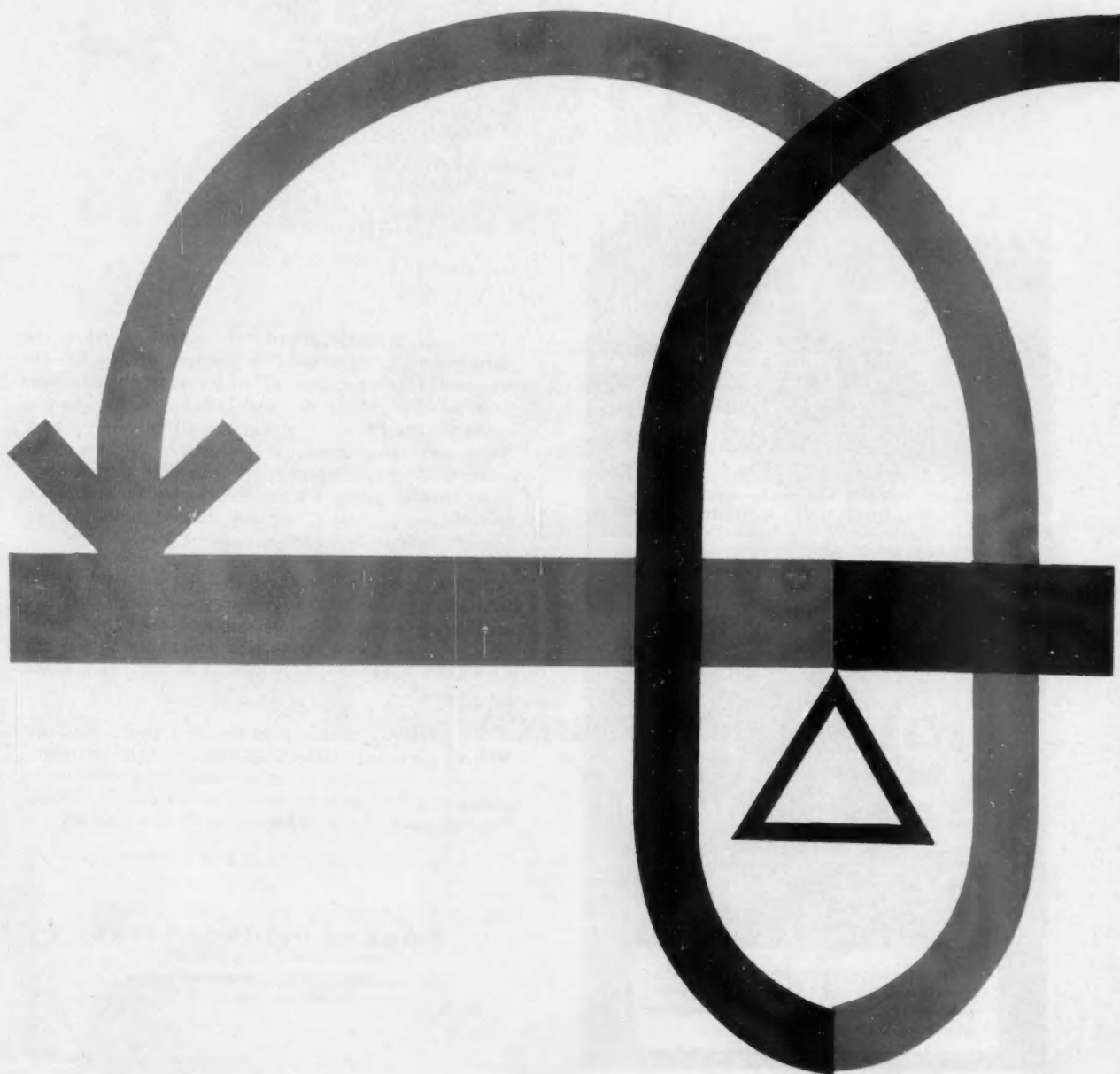
Get more information on the job being done by Vickers packaged hydraulic systems in chemical, petrochemical, petroleum refining, and other processing industries by writing today for Bulletin I5802, "Packaged Hydraulic Systems for Process Control."

VICKERS INCORPORATED
DIVISION SPERRY RAND CORPORATION

ADMINISTRATIVE and ENGINEERING CENTER
Department 1606 • Detroit 32, Michigan



ElectriK Tel-O-Sef—the true 2-wire system

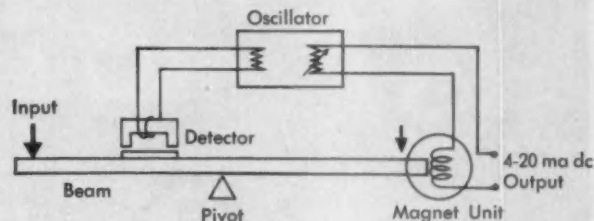


Care and feedback of delicate inputs

Delicate inputs thrive on the tender care of *ElectriK Tel-O-Set's* force-balance feedback system. This system, used as the basic circuit in *Tel-O-Set* transmitters, receivers, controllers, and other instruments, has proved itself in thousands of installations in the last five years. The force-balance feedback circuit increases the accuracy and dynamic response of the system by decreasing hysteresis effects and sensitivity to changes in ambient conditions.

Observe: (1) input force (from bellows, Bourdon tube, or displacement linkage) deflects pivoted beam; (2) air-gap in ferrite detector increases, (3) producing a change in inductance in oscillator circuit; (4) a portion of output current is fed back into magnet unit, producing a force on beam which is equal and opposite to input force; feedback balances beam. Full scale motion is only one-thousandth of an inch.

The advanced control engineering seen in force-balance feedback is carried through the entire *ElectriK Tel-O-Set* System. Specifically, there's no external power required at any field-mounted *Tel-O-Set* instrument. Line power connection is made only at the receiver. Two-wire d-c transmission eliminates shielding problems. The 4-20 milliamp signal range of the system gives a live zero and permits the use of the most reliable transistors available. The d-c signals



can be fed into data handling systems and millivolt-actuated instruments . . . can be easily transduced to a standard 3-15 psi pneumatic signal to operate existing pneumatic systems.

Take a new look at your control applications with the *ElectriK Tel-O-Set* System in mind! Get complete technical data from your local Honeywell field engineer. Call him today . . . he's as near as your phone. MINNEAPOLIS-HONEYWELL, 21 Penn Street, Fall River, Massachusetts.

Honeywell



First in Control

SINCE 1885

75
YEAR

PLANNING THE FUTURE

NEW CLARY SCANNING PRINTER ACCEPTS

BOTH DECIMAL AND CODED DATA...

ON SAME LINE...AT NO EXTRA COST...

from digital voltmeters,
shaft position transducers,
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meters, step switch banks,
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...draws negligible
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...and color-prints in black and red at three lines per second,
with a capacity of 12 digits per line. Full manual keyboard is standard.
For more information on the Clary Model 1961 Scanning Printer,
write today for Engineering Bulletin No. S-III.

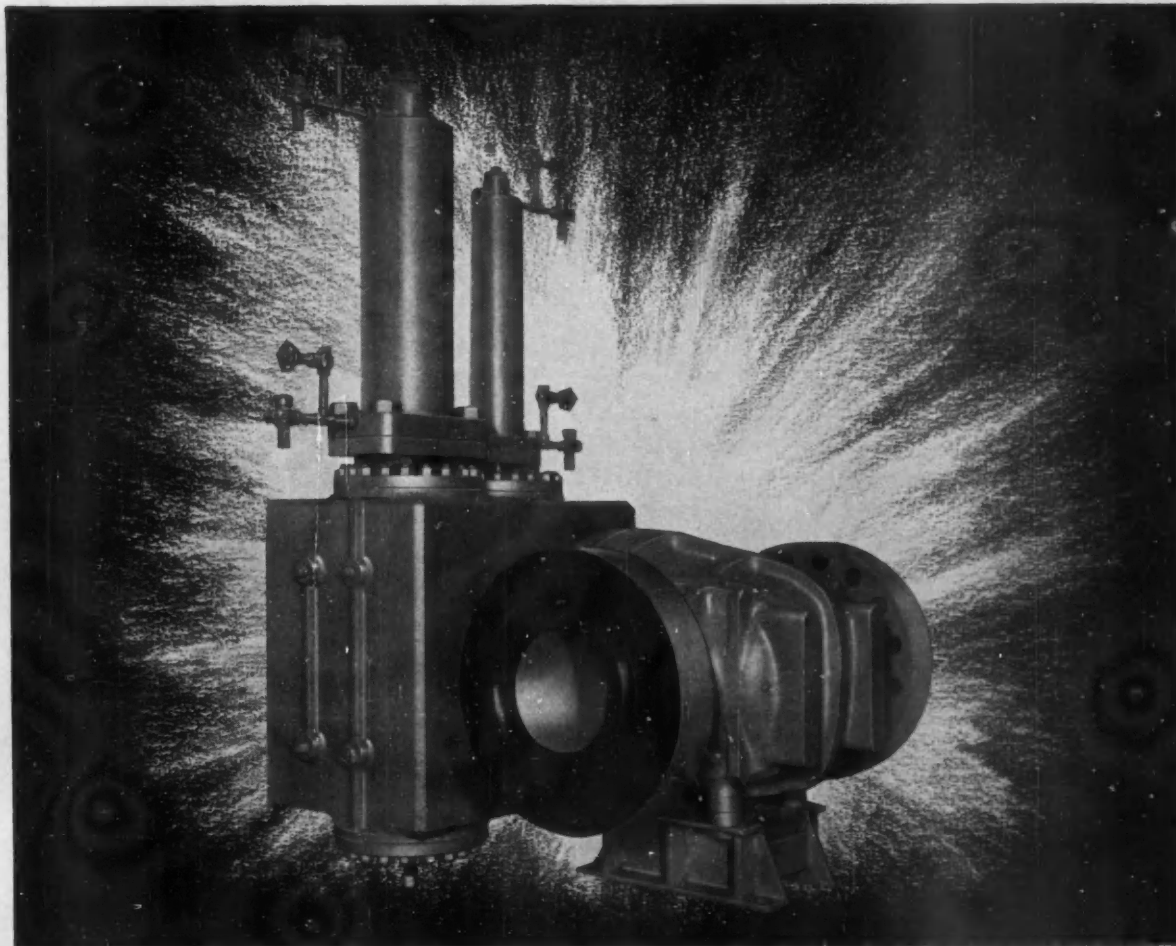
Clary

ELECTRONICS DIVISION
CLARY CORPORATION
San Gabriel, California

ALLIS-CHALMERS



A-1230



Rotovalve unit for 2700-psi, 1050 F service.

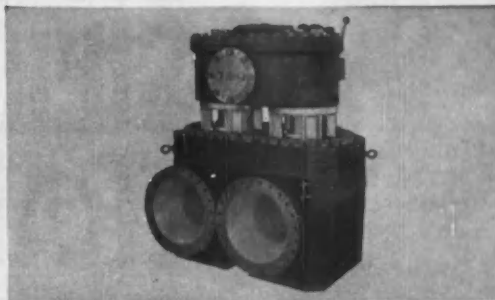
A must for nuclear reactor service... valves that **seat tighter with use**

Rotovalve units accurately control or shut off in high-temperature, high-pressure reactor applications. Units feature lantern ring with double packing, pressurized with the line fluid or purged to a bleed tank at lantern ring.

One example of current manufacturing is a 10-inch *Rotovalve* unit for operation at 2500 psi, 2500 F. Also being engineered is a 12-inch size for service at 4000 psi, 4000 F. Still another type combines a pair of valves within a single housing for use on dual, concentric pipes. Inner pipe carries 1400 F CO₂ to reactor; outer, 700 F CO₂ away from reactor.

Your Allis-Chalmers representative can arrange reactor valving engineered to your specific requirements. He also supplies a complete line of butterfly valves, including models for air-lock valving. *Contact him for detailed information, or write Allis-Chalmers, Milwaukee 1, Wisconsin.*

Rotovalve is an Allis-Chalmers trademark.



Duplex Rotovalve unit features a single operator — controls 1200-psi, 600 F steam, or 1500-psi, 300 F air. Operator allows both valves to open simultaneously, or one to open while the other closes. Saves space vital where entire reactor unit must be enclosed in radiation-proof structure.

new low prices

ON WESTINGHOUSE SILICON POWER TRANSISTORS

PRICES
REDUCED
UP TO 40%!

AVAILABLE NOW IN ANY QUANTITY! Now you can have the proven quality and reliability of Westinghouse Silicon Power Transistors at the lowest cost yet. Types 2N1015 and 2N1016 are available in 30, 60, 100, 150 and 200 volt ratings in production quantities to meet your requirements at all times. Because these transistors have **True Voltage Ratings**, they can be operated continuously at full published voltage ratings without risk of failure.



Other Westinghouse Transistor advantages include:

- High Power... up to 150 watts
- Collector current to 7.5 amperes
- Junction temperature to 150°C
- Designed to meet or exceed MIL specifications
- Extremely low saturation resistance

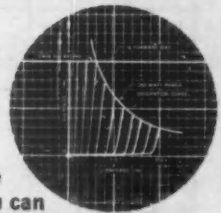
Present industrial and military applications include: Inverters • Regulators • Amplifiers • High Power Switching • Telemetry • Guidance • Powersupplies.

For additional information, and quotation of new low prices, call your nearest Westinghouse representative or semiconductor distributor. Or write: Westinghouse Electric Corporation, Semiconductor Department, Youngwood, Penna. You can be sure if it's

Westinghouse



Each Westinghouse Silicon Power Transistor is guaranteed by 100% power testing before shipment.



True Voltage Ratings—you can operate Westinghouse Silicon Power Transistors at full rating without risking transistor failure.

For immediate "off-the-shelf" delivery, order from these Westinghouse distributors:

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 KANN-ELLERT ELECTRONICS, INC. Baltimore, Md./TU 9-4242
 MILGRAY ELECTRONICS New York, N.Y./RE 2-4400
 RADIO & ELECTRONIC PARTS CORP. Cleveland, Ohio/UT 1-0060
 SCHNEIDER ELECTRONICS Long Island, N.Y./PI 6-0520

MIDWESTERN

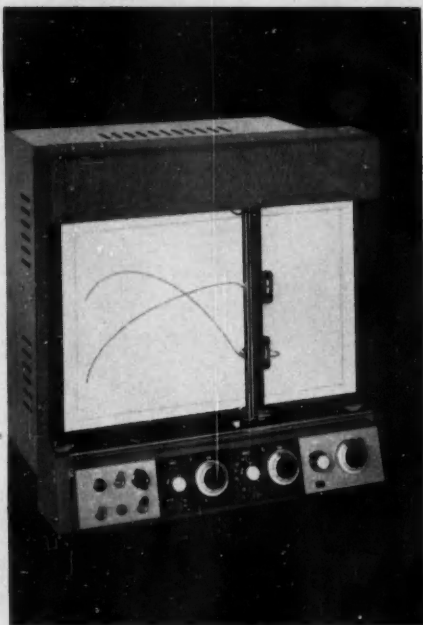
ELECTRONIC COMPONENTS FOR INDUSTRY CO. St. Louis, Mo./WO 2-9917
 INTER-STATE RADIO & SUPPLY CO. Denver 4, Colo./TA 5-8257
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WESTERN

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CIRCLE 63 ON READER SERVICE CARD

Moseley 4B AUTOGRAF Recorder



PLOTS TWO DEPENDENT VARIABLES AGAINST SINGLE INDEPENDENT VARIABLE

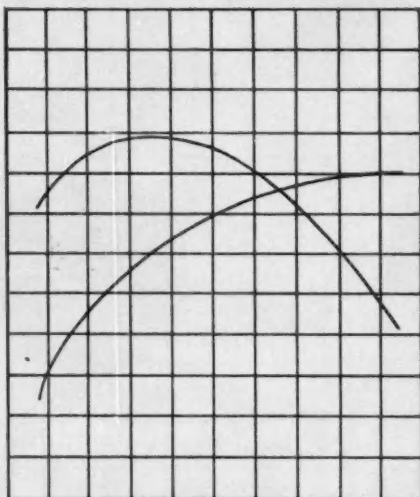
The MOSELEY Model 4B Recorder simultaneously plots two dc input signals against a third signal in cartesian coordinates on standard graph paper.

An internal X-axis time base permits plotting two variables against time.

Three pens are employed; one a fixed pen serving as an event marker to identify significant points during recording. Plotting pens are controlled by independent servos; electrically isolated separate amplifiers eliminate interaction and filters smooth noisy signals for a superior plot.

Model 4B employs either 11" x 17" or 8½" x 11" paper with continuous vacuum hold-down. Transfer switches on range controls permit arbitrary fitting of the voltage to any part of the chart.

The instrument is rack mounted with a vertical recording surface, tilted front control panel, and input connections at the rear.



SPECIFICATIONS

Recording Mechanism:	Independent servo drives for X ₁ , Y ₁ , Y ₂ axes; free of ground.
Paper Size:	8½" x 11", 11" x 17", vacuum hold.
Recording Speed:	1½" sec on X axis, ¼" sec on Y axis for full scale travel.
Input Voltage Ranges:	X axis: 10 ranges, 7.5 mv to 150 v Y axis: 10 ranges, 5 mv to 100 v
Time Intervals:	5 ranges, 7.5 to 750 sec full scale travel (X axis)
Input Resistance:	200,000 ohms/v up to 2 v range; 2 megohms on higher ranges.
Accuracy:	Better than 0.2% full scale. Resetability better than 0.1% full scale.
Power:	115 v, 60 cps, 100 watts. (Other voltages and frequencies to order)
Price:	\$3,450.00 f.o.b. factory.

Data and price subject to change without notice.

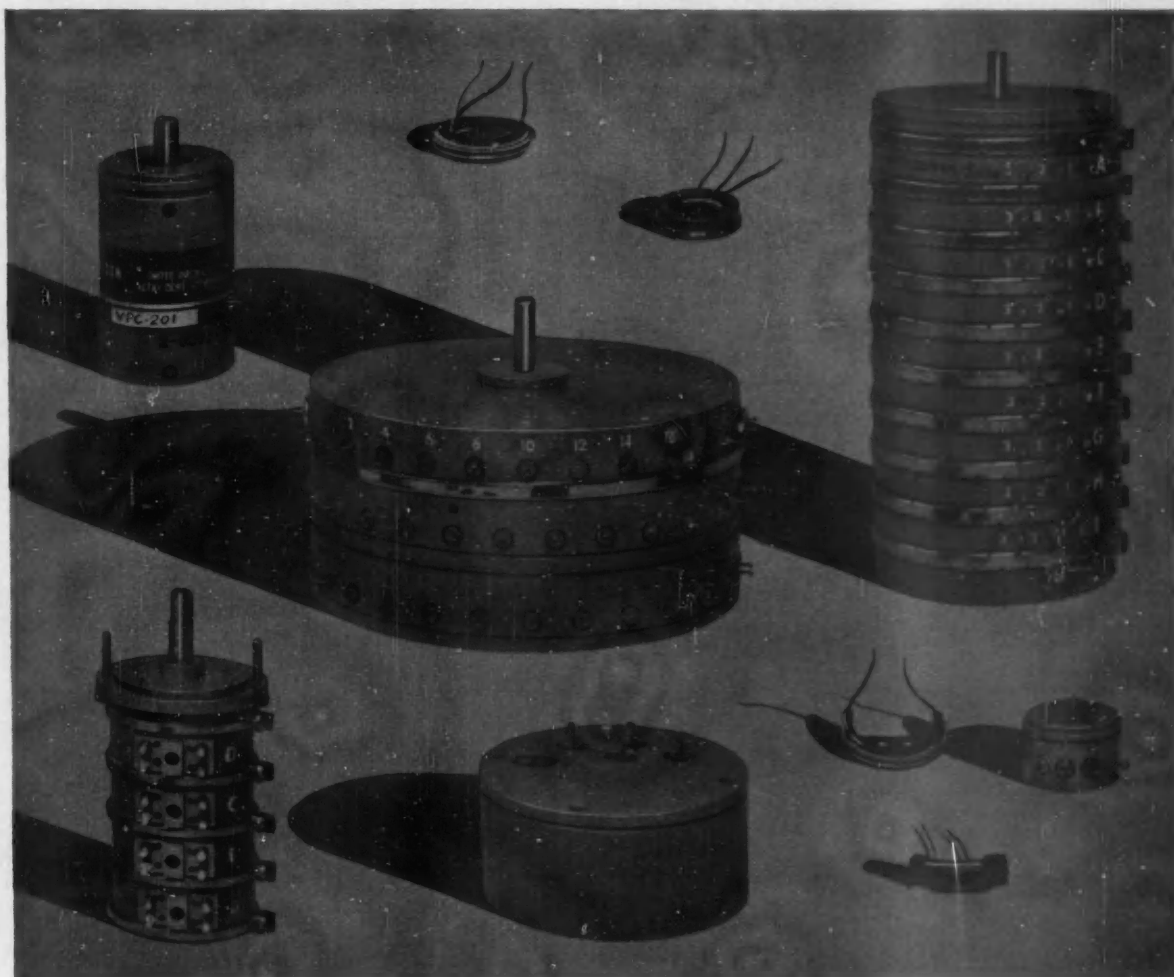
AUTOGRAF

pioneer and leader in X-Y and strip-chart recorders

recorders

F. L. MOSELEY CO.

Dept. H-10 409 N. Fair Oaks Avenue, Pasadena, California
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A collection of special Ketay potentiometers including single turn, multi-turn, ganged, sector, pendulum and pick-off types. Both linear and non-linear models are included.

Call on Ketay for your Precision Potentiometer Requirements

Ketay has capabilities for designing and manufacturing specialized as well as standard precision potentiometers. Ketay can fulfill a wide range of requirements with potentiometers offering these superior features:

PRECIOUS METAL or base metal windings meet temperature coefficients, low torque and low noise level requirements.

WELDED TAPS permit high resolution since there are no shorted turns in the tap region. Ketay-designed equipment enables wire to be welded $1/5$ the diameter of a hair.

OPTIMUM ACCURACY for all diameters—Ketay's exclusive servo-controlled winding machines assure constant tension and accurate spacing of turns. Conformity of 0.05% and better within a 3" diameter is an example of Ketay potentiometer accuracy.

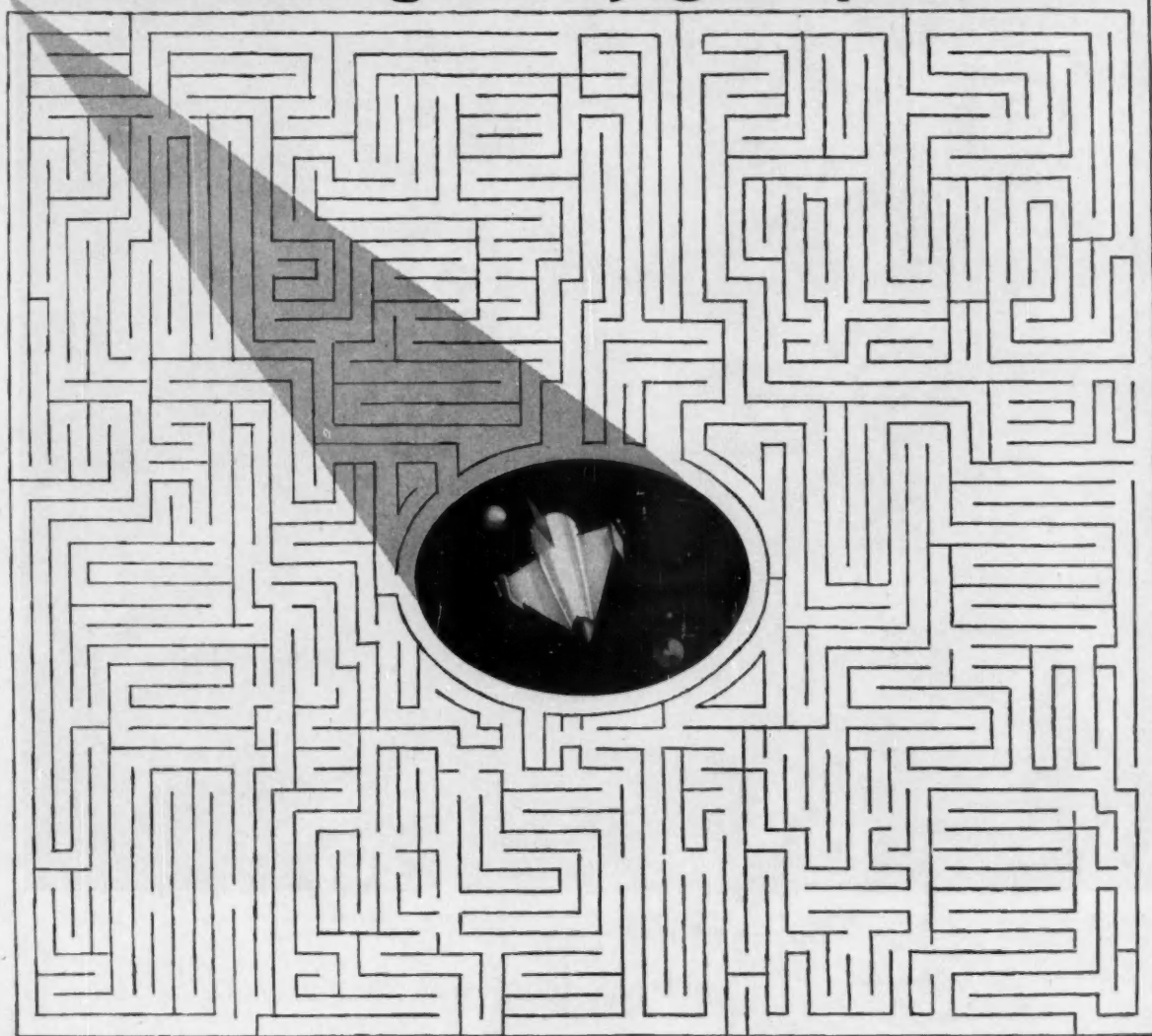
HIGH TEMPERATURE (to 300°C) and nuclear resistance.

Ketay can supply precision potentiometers to generate functions such as sine, cosine, tangent or exponential and empirically derived curves. Units can be designed for almost any environment. Detail your exact specifications and mail to us at



KETAY DEPARTMENT
NORDEN DIVISION
UNITED AIRCRAFT CORPORATION
COMMACK, LONG ISLAND, NEW YORK

Kidde's solving the Cryogenic puzzle! ▶



How do you design cryogenic fuel power systems for space vehicles? Right now, Kidde is solving this problem for the Air Force.

Step by step, stage by stage, Kidde is defining and analyzing all factors... from tankage to secondary power to environmental and reaction control requirements. The result will be the solution to integration of all of these sub-systems into the optimized cryogenic power system for space vehicles.

Kidde's advanced cryogenic capability can solve your problems in this field. Put Kidde to work for *you*.



Kidde Aero-Space Division

Walter Kidde & Company, Inc. 1017 Main St., Belleville 9, New Jersey

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NEW!

HONEYWELL VISICORDER MODEL 1406

direct-recording oscillograph



A fourth outstanding instrument has joined the Honeywell Visicorder family—the new Model 1406, an efficient, dependable direct-recording oscillograph capable of recording up to six simultaneous dynamic functions and producing immediately readable permanent records without inks, styli, heat, powders, or chemical processing.

Designed to take full advantage of the ultra-violet Visicorder principle, the 1406 provides today's most advanced recording method at an extremely reasonable price. For only \$1845, you can own a complete six-channel Visicorder, including galvanometers, grid line system, and built-in timer, while a two-channel model is available for just \$1255. Because it is less complex than other Visicorder models, the 1406 greatly reduces the per-channel cost of acquiring and recording data.

* Prices range from \$1255 to \$1845



FEATURES AND SPECIFICATIONS— MODEL 1406 VISICORDER

Now, for the first time, users whose recording requirements lie in the middle frequency range may obtain genuine Visicorder performance without paying a premium for more sophisticated equipment. Depending upon the galvanometers you choose, the 1406 will record variables with frequencies as high as 200 cps, making it the ideal instrument for the majority of applications as found in normal laboratory testing and evaluation. The 1406 is easily tailored to your individual needs; it may be ordered with a choice of galvanometers and record drive speeds, and is available with or without grid line and/or timing systems. In addition, the new Model 1406 provides many user economies—among them, negligible lamp replacement costs and lower power consumption—than upper frequency range instruments.

Use the 1406 for circuit analysis . . . for current studies . . . for a near-infinite number of other applications which you will discover for yourself. As with all Honeywell Visicorders, the 1406's usefulness and versatility are limited only by the imagination of the user.

GALVANOMETERS—Choice of two natural frequencies: 42 or 330 cycles. L42-700—42 cycles; flat within 10% to 25 cycles; sensitivity 30 ua/in \pm 10%; linearity within 5% of full scale deflection (6" peak to peak maximum; 4" single deflection); damping resistance 700 ohm; coil resistance 250 ohm; maximum current 40 ma; may be operated at 500v above ground. L330-120—330 cycle; flat within 10% to 200 cycles; sensitivity 700 ua/in \pm 10%; damping resistance 120 ohm; coil resistance 800 ohm; maximum current 30 ma; other specifications same as L42-700.

BANK—Standard C-type magnet in simple adjustable mount. Dummy filler required for use with less than 6 galvanometers; adjustable reference trace optional for either end of bank.

RECORD PAPER—6" x 100' (standard base) or 6" x 150' (thin base). Uses all popular direct-recording papers.

TIME LINES (Optional)—Flashtube system; instant warm up, no parallax. Full width lines at intervals of 1, .1, and .05 sec., 1, .1, and .05 min., or 1, .1, and .05 hr., depending on choice of record speeds.

RECORD SPEEDS—Standard: 25, 5, 1 and .2"/sec. Also available: 25, 5, 1 and .2"/min.; 25, 5, 1 and 2"/hr.; 100, 50, 25 and 5mm/sec.

GRID LINES (Optional)—Choice of inches or metric. .2" spacing; every 5th line heavier for inch ranges; 5mm spacing with every other line heavier for mm ranges.

WRITING SPEED—to 3500"/sec.; **STATIC TRACE WIDTH**—.03"; **OPTICAL LEVER**—30cm (11.8"); **RECORDING WIDTH**—6" maximum; **LAMP**—70 watt incandescent; **LAMP LIFE**—rated 100 hrs. in high intensity position; **INTENSITY CONTROL**—two-position "high" or "low" switch.

POWER REQUIREMENTS—105-129v AC, 60 cps 200 watt; **OPERATING TEMPERATURE** 32° F to 135° F; **HUMIDITY**—98%; **ALTITUDE**—to 10,000 feet; **DIMENSIONS**—9" x 9" x 12"; **WEIGHT**—25 lbs.

NOW—A VISICORDER FOR EVERY RECORDING NEED

Model 906 Visicorder—906B-1, 14 channels; DC to 5000 cps; 906B-2, 8 channels; DC to 2000 cps. Both on 6" paper.

Model 1108 Visicorder—24 channels from DC to 5000 cps on 8" paper. Many automatic convenience features.

Model 1012 Visicorder—36 channels from DC to 5000 cps on 12" paper. The most versatile recording oscillograph ever made.

Write for your free copy of the 36-page Visicorder Applications Manual, a comprehensive, detailed guide book to many varied uses of the Visicorder.

For further information, including detailed price and delivery data, write:

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Honeywell

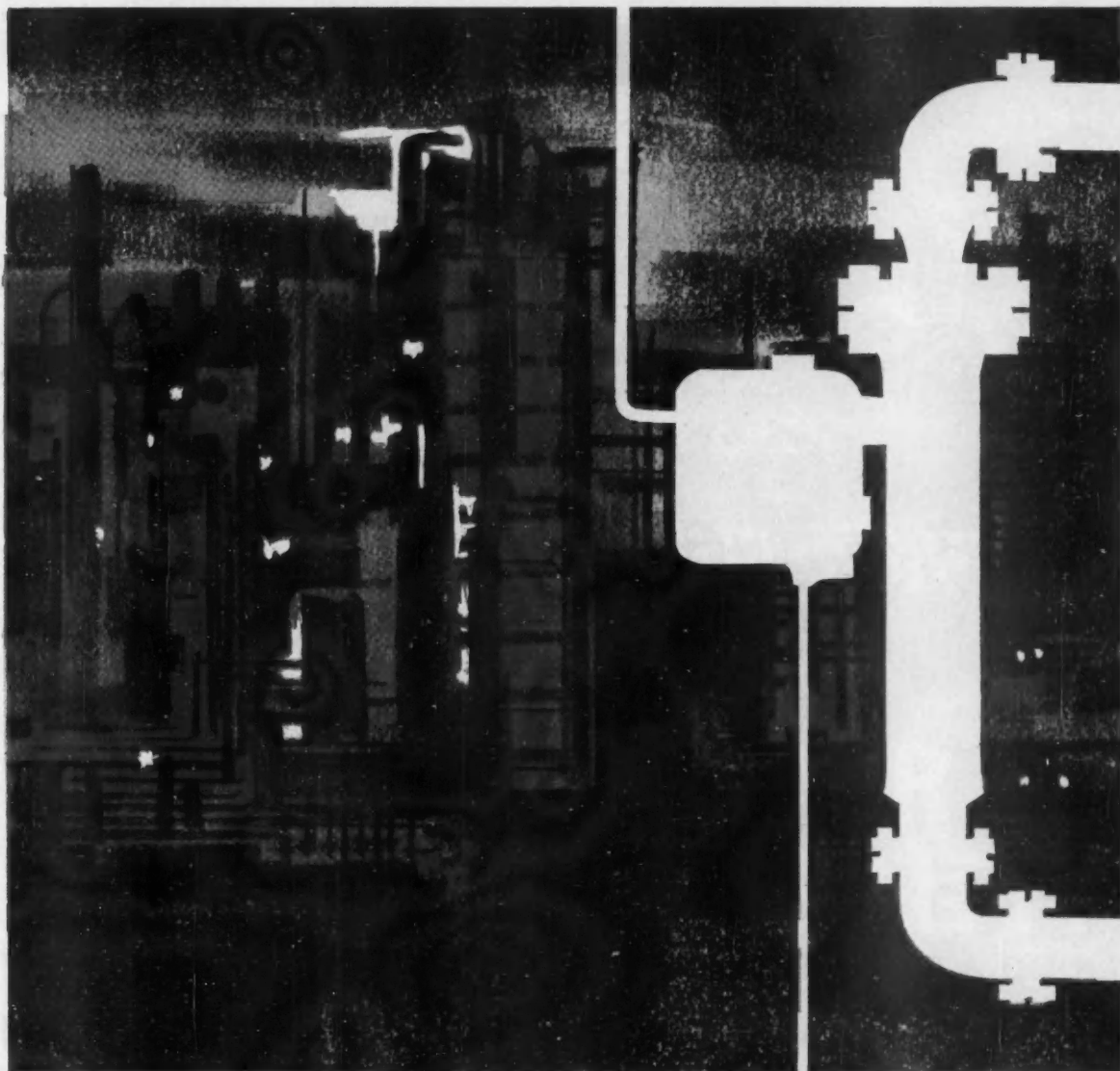
ANOTHER DIAMOND JUBILEE PRODUCT



FROM HONEYWELL



Industrial Products Group



Fisher Level-Trols—universally accepted in the power and process industries

High in sensitivity and accuracy! For full float range operation the Fisher Level-Trol is factory calibrated or zero adjusted to produce an accurate 3 to 15 psi or 6 to 30 psi signal output. Designed, engineered and universally accepted for most liquid level control, liquid level indication and interface control problems. Has simple liquid level adjustment indicating dial—combined pneumatic proportional band and specific gravity adjustment. Heavy-duty built—easy to operate—simple to service. Available with cage units for external mounting or internal top or side flange mounting with float sizes from 14" to 120".

**Write for Bulletin F4A
for full details.**



IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD...CHANCES ARE IT'S CONTROLLED BY...

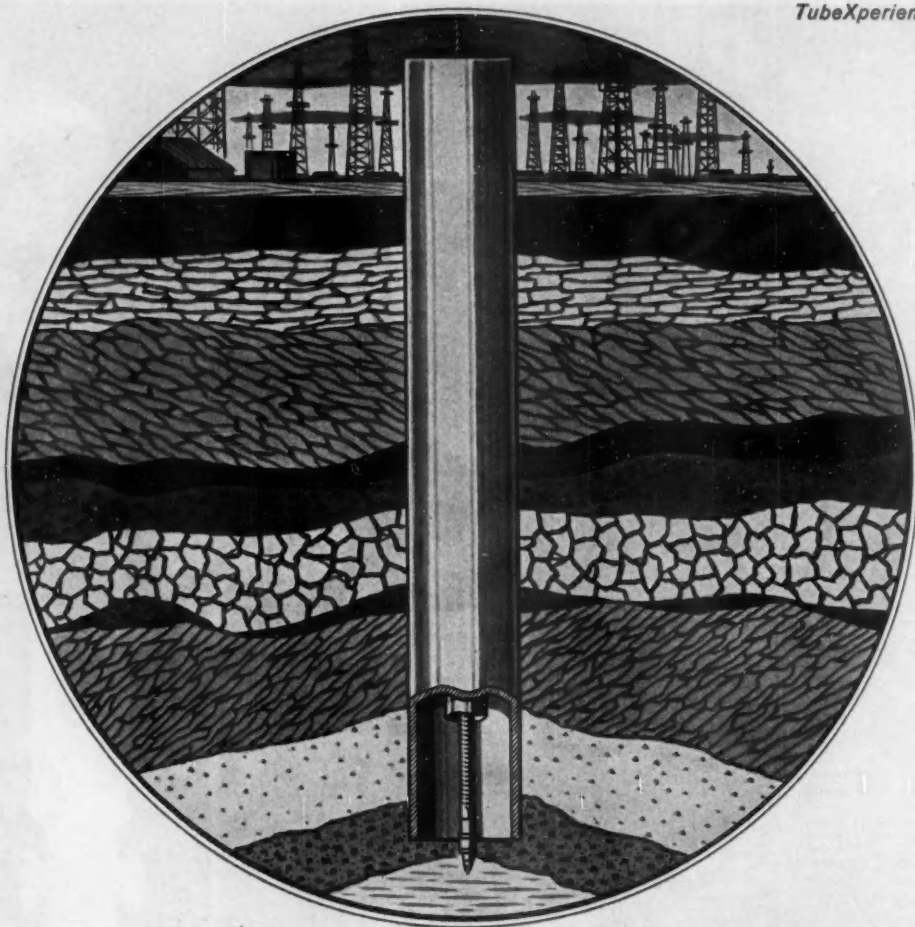
FISHER GOVERNOR COMPANY

Marshalltown, Iowa / Woodstock, Ontario / London, England



←CIRCLE 68 ON READER SERVICE CARD

CIRCLE 69 ON READER SERVICE CARD 69



Deep well pressure readings within .05% accuracy with help of Superior Ni-Span C* Bourdon Tubing

Accurate down-well pressure readings, indicating changes of only 1 to 4 psi at bottom-hole pressure of 2000 psi, are hard to get, but extremely important. They demand a pressure gage accuracy of at least 0.1% to make the vital engineering calculations based on them of any value.

To achieve this accuracy and better it, Superior was asked for help in selecting the Bourdon tube material for an improved bottom-hole measuring device. After careful study, its metallurgists recommended Ni-Span C nickel-chrome alloy for the Bourdon tubes. This material was chosen for its relative insensitivity to temperature changes, coupled with superiority in operating temperature, mechanical hysteresis, and elastic drift; also for its fatigue resistance and spring properties.

The customer followed the suggestion and now this gage,

which is unique in bottom-hole pressure instruments for the reason that it utilizes a helix-wound Bourdon tube to transmit directly the effects of pressure to a recording stylus, is rated 0.1% accurate. In fact, with special care in operations and calibration, it can measure within .05% accuracy.

NI-SPAN C TUBING NOW STANDARD AT SUPERIOR

Ni-Span C redraw stock is now in inventory at Superior, available for immediate production in a range of sizes from .010 in. to $\frac{3}{8}$ in. OD, up to .125 in. wall max., and from $\frac{3}{8}$ in. to 1 $\frac{1}{2}$ in. OD in wall thicknesses up to .035 in. max. Shaped tubing can be produced to customers' prints. Perhaps you have an application that can benefit from its unusual properties. Write for Data Memorandum No. 19. Superior Tube Company, 2026 Germantown Ave., Norristown, Pa.

*Registered trademark of International Nickel Co.

Superior Tube


The big name in small tubing
NORRISTOWN, PA.

All analyses .010 in. to $\frac{3}{8}$ in. OD—certain analyses in light walls up to 2 $\frac{1}{2}$ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

70 CIRCLE 70 ON READER SERVICE CARD

CONTROL ENGINEERING



NO VITREOUS ENAMEL POWER RESISTOR EVER OFFERED GREATER DEPENDABILITY!

Test after test by independent evaluation laboratories have proved the outstanding dependability of Clarostat Greenohm "V" vitreous enamel resistors. Be sure to always specify this proved dependability.

Available in all popular wattages, ohmages, adjustable or fixed... Write for complete information...

Greenohm V



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CLAROSTAT MFG. CO., INC.
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*direct
line
service*

**IMMEDIATE
DELIVERY!**

Your local Clarostat Distributor stocks Greenohm "V" resistors in depth—call him for fast delivery...

OCTOBER 1960

CIRCLE 71 ON READER SERVICE CARD

71

Pick a Number!

There are only four basic numbers in Fenwal's new "500" Line of Electronic Temperature Controllers and Indicators. But they provide industry with a broad choice of instrumentation *not available elsewhere!*

For example, a packaging machine manufacturer might have the problem of controlling 6 heater blocks on a unit capable of sealing a variety of films. He'd want separate control of each block — 3 "ON-OFF" and 3 proportioning — with remote adjustment of control. The Fenwal 536 Controller would give him all this. For indication during periodic checks, he'd simply add the 580 Indicator. *Price? Extremely reasonable!*

Again, a soap manufacturer might want either "ON-OFF" or proportioning control of four batch process tanks in separate plant areas — with control and indication at each point. He'd choose the Fenwal 561 Indicating Controller — a *stock unit*. He'd have no mounting problems. And with thermistor sensors, use ordinary lead wire to the supervisory panel. *As simple as that!*

Another manufacturer whose needs are only indication, might select the 582 Thermometer. And there are many *modifications* and *combinations* possible. Why not make *your* choice from these "Smarter Looking Smarter Acting" Fenwal Instruments? Write for Bulletin MC-190. FENWAL INCORPORATED, 2910 Pleasant Street, Ashland, Massachusetts.



Another
example of how



CONTROLS TEMPERATURE . . . PRECISELY

Cleveland Speed Variator is the Best Answer to *Precision Control* of Variable Speed Output



Advanced-designed Cleveland Speed Variators—available in 18 models ranging from fractional to 16 hp at 1750 input RPM—accurately provides dependable, infinitely variable speed control. They give stepless speed over a full 9:1 range—from $\frac{1}{4}$ to 3 times input speed. Instant smooth change of output speed can be adjusted by either manual, automatic or remote control. Precise adjustments are always made with accurate adherence to settings.

Thousands of Variators are in daily use on such varied industrial equipment as cigarette-making machines, textile machinery, metalworking machinery, pharmaceutical equipment, transfer tables, conveyors and experimental and testing equipment of many types.

Check these major Variator advantages:

- An extremely compact unit with input and output shafts in line and rotating in the same direction
- Almost any input speed up to 1800 RPM can be used—either clockwise or counterclockwise rotation
- Rated for constant horsepower output over a 9:1 or 6:1 range; or for constant output torque over a 6:1 range
- Speeds infinitely variable over entire range of adjustment
- No slippage—positive torque response mechanism adjusts in direct proportion to the loads encountered
- Long life and minimum maintenance due to absence of belts or complicated linkages
- Ample bearing support for overhung pulleys on both input and output shafts

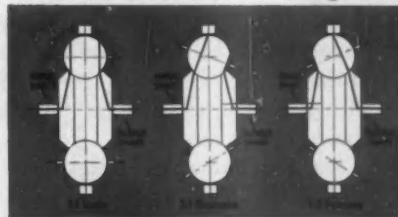
Write today for free Bulletin K-200 containing detailed description, photographs, sectional drawings, rating tables and specifications.

Cleveland Worm & Gear Division
Eaton Manufacturing Company
3260 East 80th Street • Cleveland 4, Ohio



Simple in Operation ... Built for Long Life

The Variator is an extremely compact unit with input and output shafts in line, rotating in the same direction. It incorporates ample bearing support to carry overhung pulleys.



Power is transmitted from input shaft to output shaft through alloy steel driving balls which are in pressure contact with the drive discs. Relative shaft speeds are adjusted by changing position of axles on which the balls rotate.

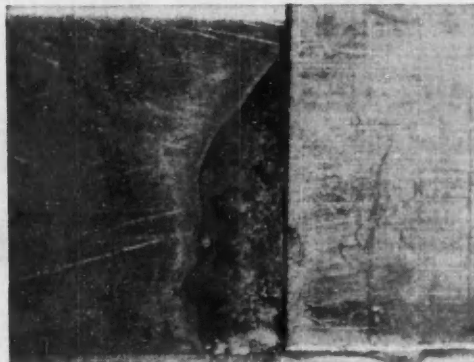
CLEVELAND
SPEED VARIATOR

Free from Thermal Fatigue

GENERAL ELECTRIC 6, 12 AND 25-AMP SILICON RECTIFIERS



SOFT SOLDER FAILURE—As soft-solder joints are stressed by cyclical loads, solder begins to re-crystallize. (Photomicrograph above shows soft solder after 7000 cycles from 25°C to 160°C.) This causes heat dissipation path of rectifier to deteriorate until junction temperature reaches melting point or thermal runaway condition, and device fails.



NO THERMAL FATIGUE — General Electric uses only hard solders in medium and high-current silicon rectifiers. (Note sound condition of G-E hard solder shown above.) Cycling tests on large samples of G.E.'s 1N2154 reveal no trace of thermal resistance deterioration after 70,000 temperature cycles from -35°C to 200°C.



A close look at the specs shows three more reasons why G-E medium currents are your best rectifier buy: (1) Lower leakage currents; (2) high surge current ratings for the new 1N1341A through 1N1206A and 1N2154 through 1N2160; (3) transient PRV ratings which let you buy only the continuous rating you need and still be fully protected for occasional transients. All units are available with negative polarity (at no extra cost) and come in a choice of hex sizes.

For the industry's fatigue-free medium-current silicon rectifiers, see your G-E Semiconductor District Sales Manager or Authorized Distributor. *In Canada:* Canadian General Electric Co., 189 Dufferin St., Toronto, Ontario. *Export:* International General Electric Co., 150 E. 42nd St., New York 17, N. Y.

Circuit designers: Make your job easier! Write for a free copy of "Characteristics of Common Rectifier Circuits." Contains basic constants you'll use every day on rectifier circuits and transformer design — all in handy, easy-reference form.

JEDEC or GE Type Number	Max Ioc @ 145°C Stud Single Phase	Repeti- tive PRV	Transient PRV	Max. Peak 1 Cycle Surge
1N1341A	6A	50	100	150A
1N1342A	6A	100	200	150A
1N1343A	6A	150	300	150A
1N1344A	6A	200	350	150A
1N1345A	6A	300	450	150A
1N1346A	6A	400	600	150A
1N1347A	6A	500	700	150A
1N1348A	6A	600	800	150A
1N1199A	12A	50	100	240A
1N1200A	12A	100	200	240A
1N1201A	12A	150	300	240A
1N1202A	12A	200	350	240A
1N1203A	12A	300	450	240A
1N1204A	12A	400	600	240A
1N1205A	12A	500	700	240A
1N1206A	12A	600	800	240A
1N248	10A	50		200A
1N249	10A	100		200A
1N250	10A	200		200A
1N248A	20A	50		350A
1N249A	20A	100		350A
1N250A	20A	200		350A
1N2154	25A	50	100	400A
1N2155	25A	100	200	400A
1N2156	25A	200	350	400A
1N2157	25A	300	450	400A
1N2158	25A	400	600	400A
1N2159	25A	500	700	400A
1N2160	25A	600	800	400A

Progress Is Our Most Important Product

GENERAL  ELECTRIC

Section S16100, Semiconductor Products Dept., Electronics Park, Syracuse, N. Y.



How to get accurate data on a small recorder

*Ampex's new CP-100 nicely balances four
desirable qualities*

Compact. Definitely, and a great advantage in trailers, in airplanes, in submarines, or even in regular laboratory use. There's complete front access to everything. All-transistor amplifiers and power supplies cut power needs and keep down the heat — an advantage in tight equipment layouts.

Portable. We'll frankly admit it takes two men to carry it — not just one and a half. But by calling in an occasional fractional man (or by using an accessory dolly) you gain exactly the needed performance that portables have lacked until now. In laboratory use, the CP-100 is "bench-top equipment."

Precise. Let the numbers talk. Though compact, the CP-100 is a full-fledged, uncompromised laboratory recorder: 200 kc response at 60 ips tape speed (and proportional at others); flutter well within telemetered-data requirements; intermodulation distortion so low it never adds spurious data of its own.

Universal. Yes, in numerous ways. The CP-100 isn't fussy about power; takes 115 or 230-volt AC at 50, 60 or 400 cycles or 28-volt DC from batteries or generator. Kinds of data: direct or FM-carrier, by interchangeable plug-in amplifiers. And it records and plays back as well.

The essential data

Model: CP-100 Compact Recorder/Reproducer. **Reel size and tape width:** 10½-inch reels with ½- or 1-inch tape (as specified). **Types of recording:** direct or FM carrier by plug-in interchangeable amplifiers. **Tape speeds:** 60, 30, 15, 7½, 3¾ and 1½ ips. **Frequency response:** direct, 300 to 200,000 cps \pm 3 db at 60 ips; FM carrier, 0 to 20,000 cps at 60 ips; response at other speeds proportionate. **Tape compatibility:** yes, with Ampex FR-600, AR-200 or interchangeable with FR-100, FR-1100, 300 and 800 series.

May we tell you more? Please write

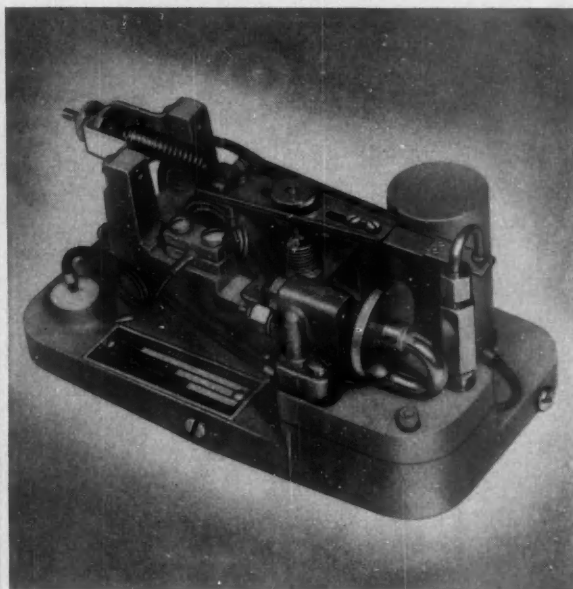


AMPEX

AMPEX DATA PRODUCTS COMPANY
Box 5000 • Redwood City, California • EMerson 9-7111

The compact SENSIRE Transmitter measures only $7\frac{3}{4}'' \times 4\frac{3}{4}'' \times 4\frac{1}{4}''$. Weighs only 7 lbs. Suitable for many types of application.

Interchangeable, all-welded thermal system. Bi-Metal case compensation. Especially desirable on low temperature applications and where mercury is not acceptable.



New from Taylor... **GAS-ACTUATED SENSIRE* TRANSMITTER**

This new version of the time-proven SENSIRE Transmitter makes low-cost temperature measurement available for those applications where mercury actuation is not acceptable. A force-balance type transmitter, No. 202TG is compact, sturdy and extremely dependable. Adjustments are simplified; repeatability is excellent.

- Available in 3 range spans. 100°F., within limits of minus 400°F. to +300°F.; 200° and 400°F., within limits of minus 400°F. to +1000°F.
- Maximum overrange protection—100% of range span above operating range.
- Calibration accuracy within 1% of range span below 550°F.; 1½% above 550°.
- Ambient case temperature limits—minus 30° to +150°F.
- Air supply—20 psi recommended; 25 psi maximum.
- Air consumption—0.4 scfm.
- Bulb size— $11/16'' \times 5\frac{1}{4}''$. (Optional capillary bulb gives temperature averaging effect. Permits variable immersion with no loss of accuracy.)

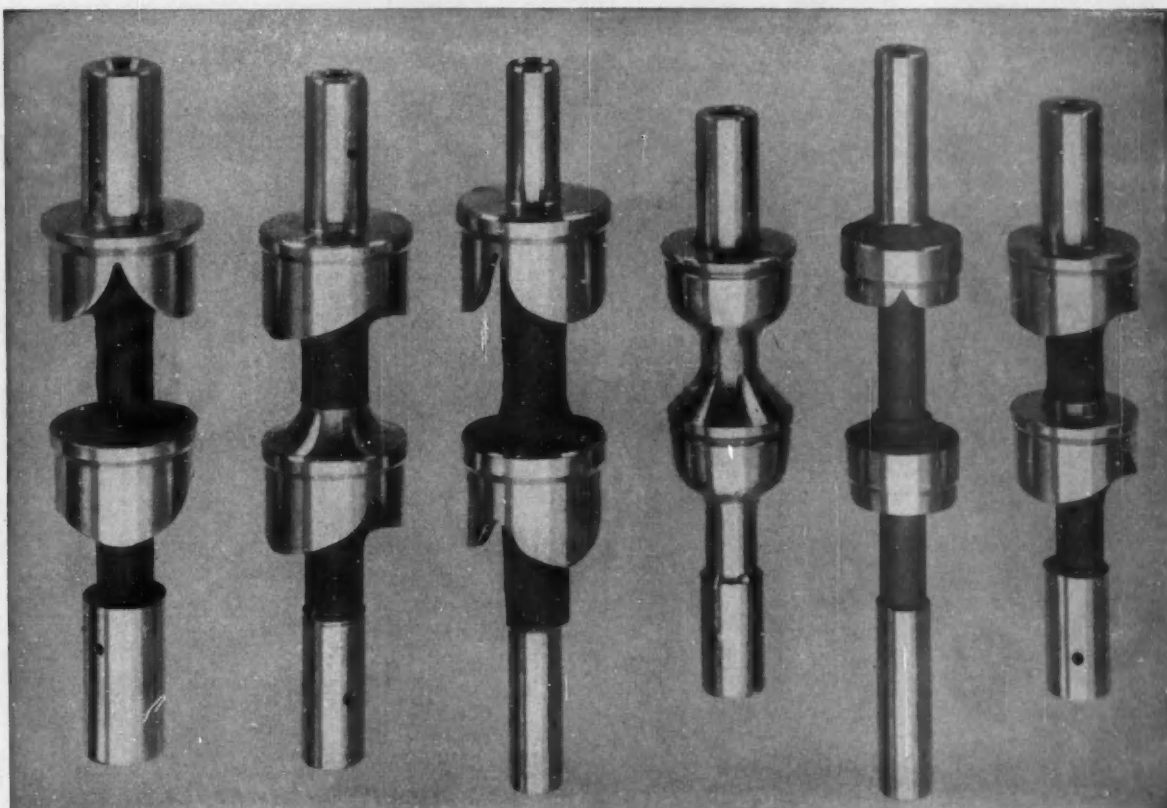
Ask your Taylor Field Engineer, or write for Bulletin 98293. Taylor Instrument Companies, Rochester 1, New York, and Toronto, Canada.



Easy to install. Mounts in any position. Universal bracket provides for direct mounting on pipe, wall or wrench head of well or separable bushing.

*Trade-Mark

Taylor Instruments **MEAN ACCURACY FIRST**



Inner secrets of inner valves

FACTS EVERY CONTROL VALVE USER SHOULD KNOW

This is a rare photograph . . . presented in a completely unretouched form. It shows the inner valve of leading makes of diaphragm control valves. The inner valve determines the control result.

The most amazing fact is the size . . . all are listed as two inch valves. All are high lift. But compare them.

Note the KIELEY & MUELLER inner valve at the far left. It equals the others on every point of con-

sideration; exceeds on many. Look at the diameter across the skirt . . . that's one reason for the remarkable C_v of K&M valves. Look at skirt length; the solid, not fabricated, design. Measure the rugged guide posts and the large column. Examine the machining and the super-finishing.

It's no wonder . . . K&M is the valve that likes to be compared. It's a better valve and a better value by every measure of comparison.



FOR THE COMPLETE FACTS . . .
write for the K&M Valve Engineer-
ing Data Catalog, Bulletin CV53.

diaphragm control valves

K&M

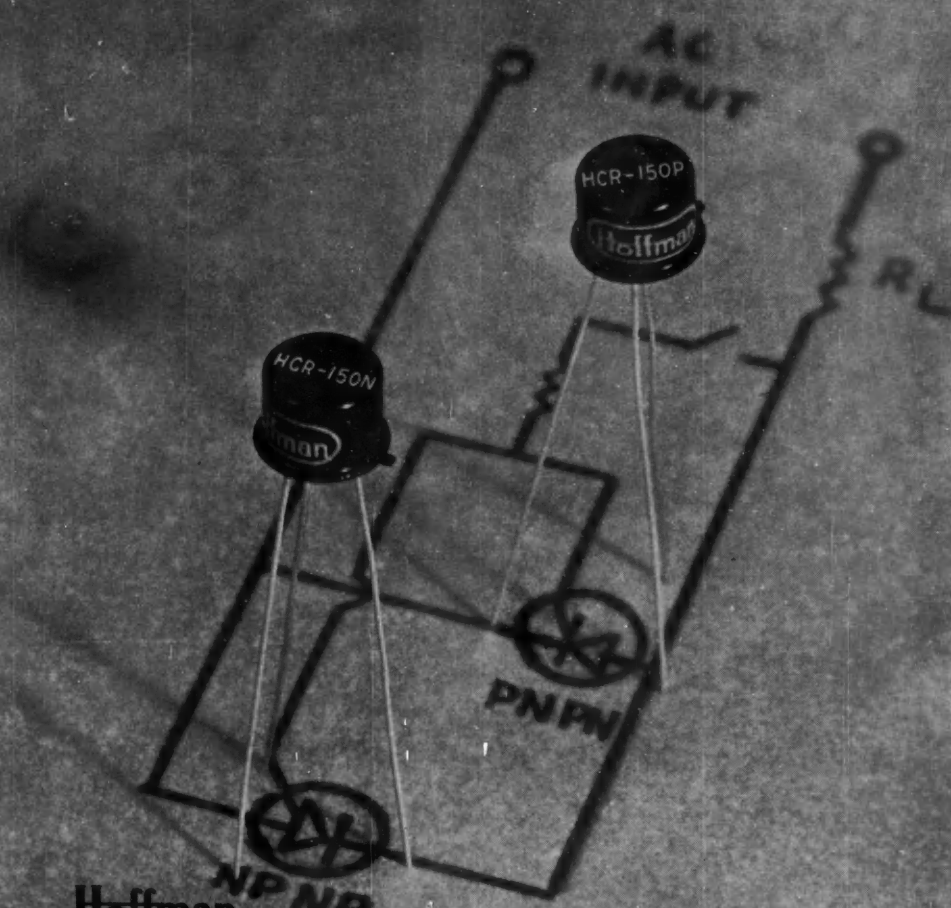
Our 78th Year

KIELEY & MUELLER, INCORPORATED

Oldest Pressure and Level Control Valve Manufacturer
64 Genung Street, Middletown, New York

OCTOBER 1960

CIRCLE 77 ON READER SERVICE CARD 77



Another First From **Hoffman**

COMPLEMENTARY SILICON CONTROLLED RECTIFIERS

- RATED 1 AMP AT 80°C
- IN TRANSISTOR TO-5 PACKAGE
- FROM A SINGLE SOURCE

Designed and built to improve the reliability of your system

- by simplifying circuitry
- by saving weight and space
- by increasing design flexibility

TYPICAL APPLICATIONS

Missile and aircraft control systems, industrial control systems, static switching, conversion and regulation, relay drive circuits, and related applications.

		SPECIFICATIONS (-55°C to +125°C)		MAXIMUM RATINGS (-55°C to +125°C)	
Hoffman Type No. 1	JEDEC Equivalent	VR and VR (volts)	Max. Vg @ 1A (volts)	Vg (off) and Vg (volts)	IGD (amps)
PNPN-1 AMP @ 80°C					
HCR-30P	—	35	2	30	1.4
HCR-50P	2N1565	50	2	50	1.4
HCR-100P	2N1566	100	2	100	1.4
HCR-150P	—	150	2	150	1.4
HCR-200P	2N1567	200	2	200	1.4
HCR-300P	2N1568	300	2	300	1.4
HCR-400P	2N1569	400	2	400	1.4
NPNP-1 AMP @ 80°C					
HCR-30N	—	30	2	30	1.4
HCR-50N	2N1565*	50	2	50	1.4
HCR-100N	2N1566*	100	2	100	1.4
HCR-150N	—	150	2	150	1.4
HCR-200N	2N1567*	200	2	200	1.4

NOTES: (1) Average rectified forward current. (2) Suffix "P" denotes positive gate polarity referred to cathode (standard device). Suffix "N" denotes negative gate polarity referred to anode (complementary device). (3) Derate 20 mA/°C above 80°C. (4) JEDEC complement.

Hoffman / **ELECTRONICS CORPORATION**
Semiconductor Division



1001 Arden Drive, El Monte, California

TWX: El Monte 9735

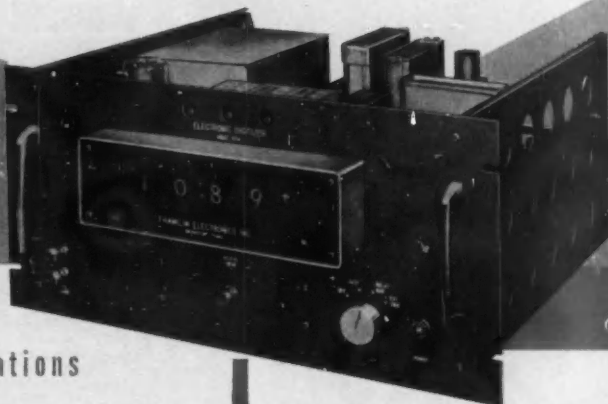
Plants: El Monte, California and Evanston, Illinois

long-term stability... ONE YEAR

MODEL 1310N A-to-D CONVERTER/VOLTMETER

There's never any need for exasperating knob twiddling with a Franklin Model 1310N. Magic? No, just plain practical design. All operating potentials, including the line voltage, are regulated before they're put to work. What's more, there are no stepping switches, relays or other mechanical components to introduce noise or delays... it's all-electronic for whisper-smooth voltage conversion... and with a stability never before equalled. The brief specs tell more.

MODEL 1310N, ALL
ELECTRONIC ANALOG-
TO-DIGITAL CONVER-
TER/VOLTMETER.....
\$2090*



request
data sheet 2006

brief specifications

RANGES:	000.0 to 120.0 V dc. Input sensitivity: 0.1 V per digit. Matching amplifiers are available with minimum ranges of 1 mv per digit or 100 uv per digit.
RANGE AND POLARITY SWITCHING:	Optional automatic or manual (with amplifier).
ACCURACY (ABSOLUTE):	\pm one count (\pm 0.1% of full scale) after 10-minute warmup.
STABILITY:	Absolute accuracy is maintained for at least one year without calibration.

INPUT IMPEDANCE:	100 megohms.
READOUT TIME:	Maximum of 12.2 milliseconds to 120.0 volts full scale.
SPEED:	Up to 40 readings per second.
POWER:	100—125 V, 60 cps, 200 watts.
DIMENSIONS:	19" rack panel unit, 8 3/4" H x 15" D.
WEIGHT:	Approximately 50 pounds.

*Prices are F.O.B. BRIDGEPORT, PENNSYLVANIA.



FRANKLIN

electronics, inc.

BRIDGEPORT
PENNSYLVANIA

VAN NUYS
CALIFORNIA

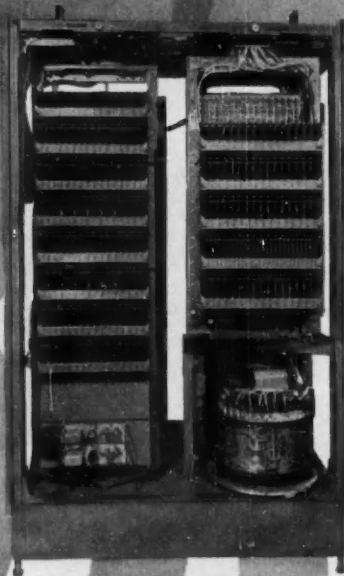
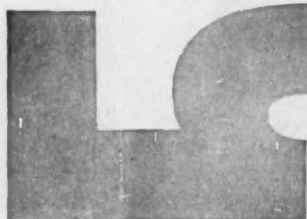
You count best when you count on FRANKLIN

predict system performance

With Link Digital Function Generator

The Link DIGITAL FUNCTION GENERATOR—another new DIALOG* sub-system, is ideal for research, simulation and control of complex systems where an extreme number of functions of one, two or more variables are defined by discrete values.

Standard signal levels for input and output circuits assure compatibility with standard analog equipment. Utilizing the greatest possible accuracy and stability combined with high speed computation, the DIGITAL FUNCTION GENERATOR delivers fast readouts of generated function in digital or analog form. This unique systems tool guarantees flexibility, ease of maintenance and remarkably low cost.



GENERAL SPECIFICATIONS

Computer type:	Special purpose serial digital
Number base:	Binary
Mode of operation:	Parallel
Memory type:	Magnetic Drum
Drum speed:	3,000 RPM
Memory capacity:	330,000 bits on 80 tracks
Word length:	32 bits
Interpolation rate:	800 per second simultaneous computation of division and multiplication
Function generation:	One variable: 0.02 sec/point Three variables: 0.1 sec/point
Accuracy:	0.1% dependent on programming accuracy

INPUT / OUTPUT CHARACTERISTICS

Input: (Continuous electrical analog signal)
Number of inputs: 64 (expandable)
Sequence: By computer command
Level: 0 to +100 volt
Conversion time: 936 microseconds

Output:
Number of outputs: 80 (expandable)
Selections: Fixed or by mode switch
Level: 0 to +100 volt
Drift: 24 millivolts in 16 hours

Output:
Number of outputs: 128
Signal: 12 binary bits at a frequency of 204.8 kilocycles per second
Pulse level: 0 to -10 volt

Write to Dept. XX, Industrial Sales Department, for specific details on the many advantages and applications of the Digital Function Generator and information on Dialog Systems Building Blocks.

**DIALOG (Link Digital-Analog Systems, Components and Building Blocks)*

LINK DIVISION
 Binghamton, New York

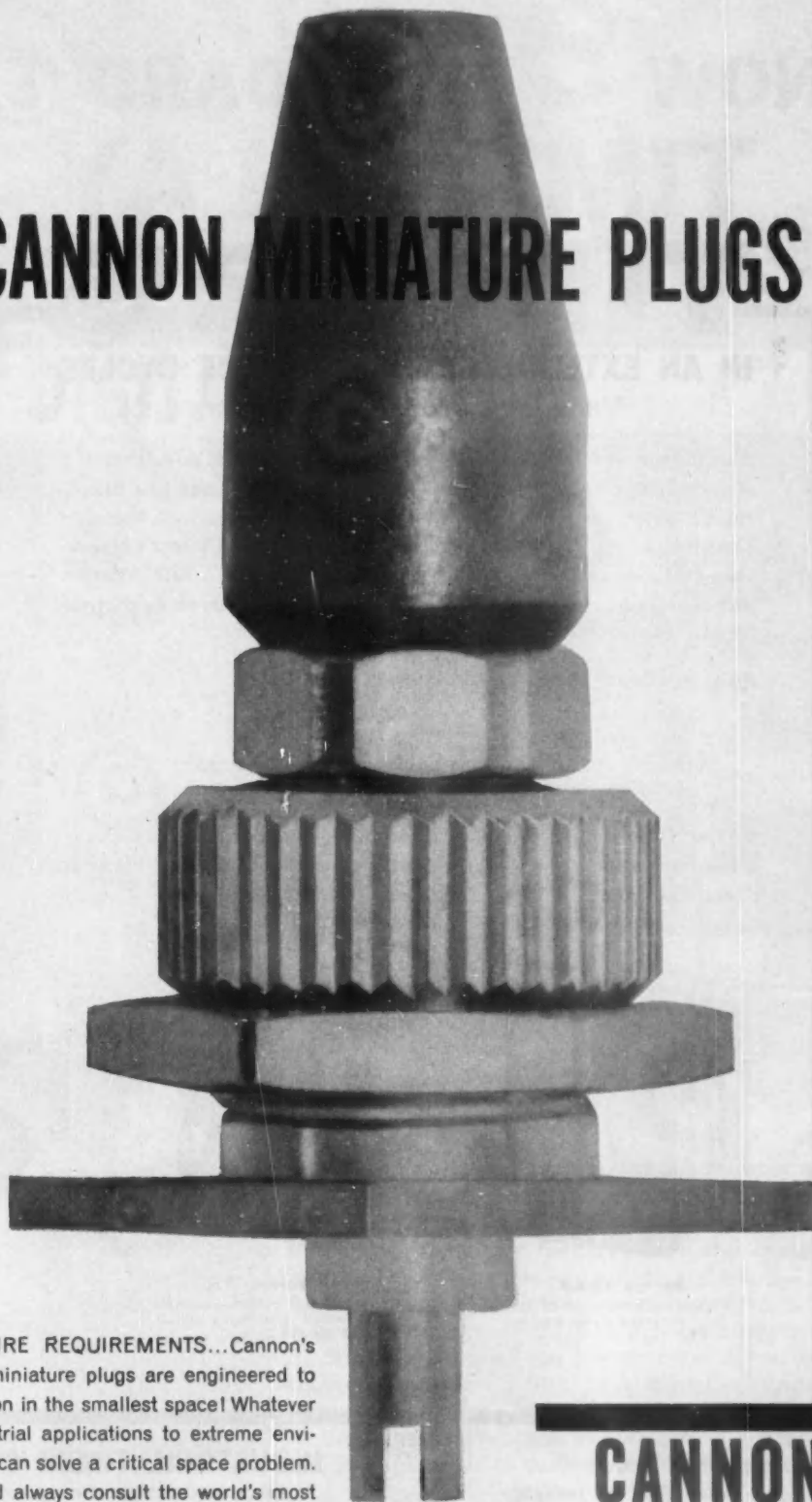


Another example of Link / Ability
GENERAL PRECISION, INC.
 Other Divisions: GPL, Kearfott, Librascope,

ACTUAL SIZE



CANNON MINIATURE PLUGS



SCALED TO YOUR MINIATURE REQUIREMENTS...Cannon's full line of miniature and subminiature plugs are engineered to provide safe electrical connection in the smallest space! Whatever your requirements — from industrial applications to extreme environmental conditions — Cannon can solve a critical space problem. Another reason why you should always consult the world's most experienced plug manufacturer...why you should consult Cannon for all your plug requirements. Write for literature to:

CANNON ELECTRIC COMPANY, 3208 Humboldt St., Los Angeles 31, Calif.



CANNON PLUGS

NOW 9 STANDARD TYPE TIME DELAY TIMERS

IN AN EXTENDED RANGE OF TIME CYCLES

$1/60$ th of a second to 24 hours

For bigger savings in OEM design and installation now, choose a standard time delay timer from Industrial Timer's expanding line to satisfy almost *every* mounting requirement... back, side, flush, through-the-panel, totally enclosed or explosion proof. Industrial Timer's bigger-than-ever selection gives you greater design latitude in both function and appearance... eliminates the need for costly custom-made controls in your specifications.

All 9 types have these special features:

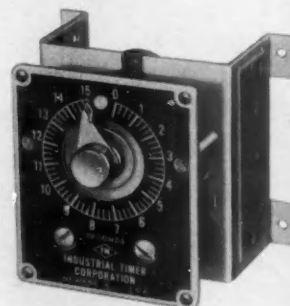
1. Actuated by momentary or sustained pulse
2. Automatic reset
3. Heavy duty load switches rated at 10 and 15 amps
4. Easy, positive adjustment of time cycles

By specifying Industrial Timer you are assured of accurate and dependable controls for applications requiring a specific time delay between circuit operations. Full details in Bulletins 300, 800 and 900.



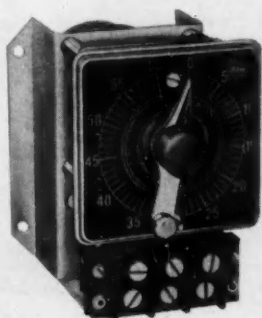
Series 90

Back-mounted, for applications where time cycle is infrequently changed or permanently fixed ($1/2$ sec. to 5 min.)



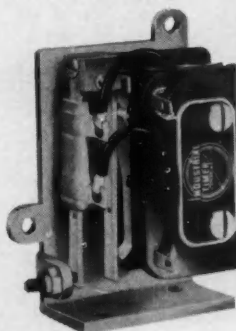
Series SF

Back-mounted (1/10 sec. to 5 min.)



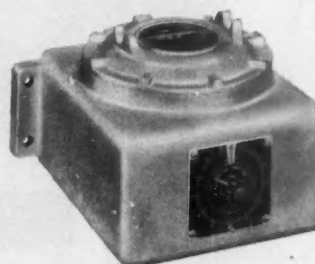
Series TDAB

Flush-, back-mounted or totally enclosed (1/60 sec. to 3 hrs.)



Series TH

Back or bottom-mounted. Thermal time delay switch. (15 sec. to 2 min.)



Series TDXP

Bottom or back-mounted. Explosion proof. External adjustments (1/60 sec. to 3 hrs.)



*Timers that Control
the Pulse Beat of Industry*

INDUSTRIAL TIMER CORPORATION

1407 McCARTER HIGHWAY, NEWARK 4, N. J.

Industrial Timer's complete line also includes: Interval Timers, Running Time Meters, Cam Timers, Explosion Proof Timers, and Programmers. Our 40-page catalog describing these is available on request.

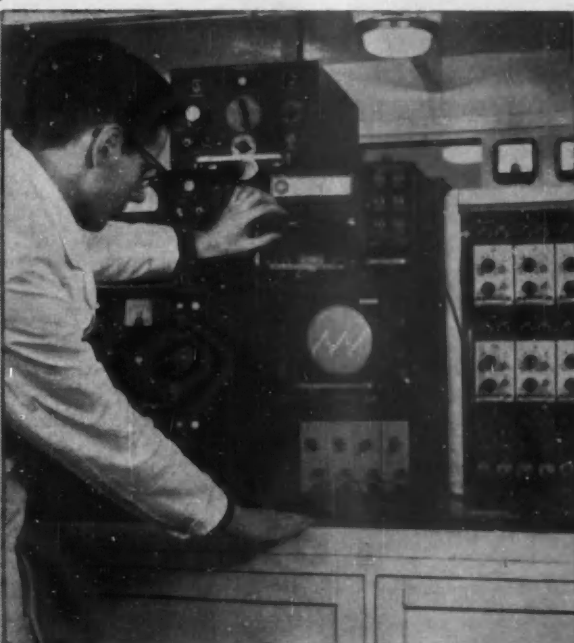
Data Handling Systems

DIGITAL



The DIDAS Transmitter

891362	108572
243895	925841
239810	189463
654958	194857
193847	237583
901205	867493
294736	910485
271057	839120
984752	856321
379824	658493
105447	539582
459233	937562
811278	423038
532485	902475
114857	521054
984735	284731
927411	883746
210473	937561
567482	109235
665820	991375
857395	274837
948573	198573
195847	958473
248571	984421
125434	103425
354321	978679
748275	213486
859483	210084
942106	330198
772689	921006



DIDAS receiving and recording in laboratory conditions

- Fully Transistorized
- Extremely High Speed
- Compact
- Reliable
- Modern Construction
- Rugged but light

Speedy measurement and analysis of data has become a necessity in modern industry. Armstrong Whitworth Aircraft have developed data handling systems for measurement and remote control. The data can be transmitted at the speed of light by radio, or by cable link, with extreme accuracy. In one system (the DIDAS vehicle system), over 250,000 different readings can be obtained in one minute. Analogue/digital and digital analogue convertors, working at over 50,000 conversions a second, eliminate processing bottlenecks. Systems can be engineered to customers' requirements.

SIR W. G. ARMSTRONG WHITWORTH AIRCRAFT LIMITED, Baginton, Coventry, England
(A member of Hawker Siddeley Aviation)

Announcing a new series of
size 8 servo components designed for
 today's high performance systems

hi-T or lo-J

(HIGH TORQUE)

(LOW INERTIA)

EAD's new line of Size 8 servo components are designed to meet the extreme environmental conditions and the reliability required by today's advanced control systems. From a family of six basic units, the design engineer has the selection of servo motors, inertially damped servo motors or servo motors with tachometer generators for "hi-T" or "lo-J" system needs.

As with all EAD components, these motors can be modified, if necessary, and can be supplied with a wide variety of integral gear reductions.

TYPICAL CHARACTERISTICS

- 26 volts per phase, 400 cycles

- Stall power per phase (watts):

hi-T 3.0
 lo-J 2.8

- Max. power output (watts):

hi-T .40
 lo-J .28

- Size 8 diameter: .750"

- Meets MIL-E-5272, MIL-E-5400.

- Ambient temperature: -55°C to +125°C.

Construction features: precision ball bearings, housing and hardened shaft all of stainless steel.

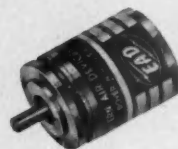
SERVO MOTORS

hi-T

Embraces high torque/watt ratio and adequate acceleration characteristics. Stall Torque, .35 oz-in.; Rotor inertia, .66 gm.-cm²; Acceleration, 37,000 rad./sec.²; No load speed, 6500 rpm; Damping coefficient, 36 dyne-cm-sec/rad.; 3.0 watts/phase @ stall.

lo-J

For low time constant and fast response to input signals in systems requiring max. torque/inertia. Rotor inertia, .17 gm.-cm²; Acceleration, 104,000 rad./sec.²; No load speed, 6500 rpm; Damping coefficient, 26 dyne-cm-sec/rad. Stall torque, .25 oz-in.



SERVO MOTORS with TACHOMETER GENERATORS

hi-T

Stall Torque, .35 oz-in.; Rotor inertia, .72 gm.-cm²; Acceleration, 34,400 rad./sec.²; No load speed, 6200 rpm; Damping coefficient, 38 dyne-cm-sec/rad.; 3.0 watts/phase @ stall; Gen. output, .250 v/1000 rpm; Phase shift, ±10°; Null voltage, 10 mv.; Gen. input, 1.7 watts.

lo-J

Rotor inertia, .23 gm.-cm²; Acceleration, 77,000 rad./sec.²; No load speed, 6200 rpm; Damping coefficient, 27 dyne-cm-sec/rad.; Gen. output, .250 v/1000 rpm; Phase shift, ±10°; Null voltage, 10 mv.; Gen. input, 1.7 watts. Stall torque, .25 oz-in.



SERVO MOTORS with INERTIAL DAMPERS

hi-T

Stall torque, .35 oz-in.; Rotor inertia, 1.0 gm.-cm²; Acceleration, 24,700 rad./sec.²; No load speed, 6000 rpm; Damping coefficient, 39 dyne-cm-sec/rad.; 3.0 watts/phase @ stall; Flywheel damping, 60 dyne-cm-sec/rad.; Corner freq., .98, 2.8 and 18.5 cps.

lo-J

Rotor inertia, .54 gm.-cm²; Acceleration, 32,700 rad./sec.²; No load speed, 6000 rpm; Damping coefficient, 28 dyne-cm-sec/rad.; Flywheel damping, 60 dyne-cm-sec/rad.; Corner freq., .77, 2.8 and 16.4 cps. Stall torque, .25 oz-in.



SEND FOR COMPLETE TECHNICAL DATA



EASTERN AIR DEVICES, INC.

SUBSIDIARY OF NORBUTE CORPORATION

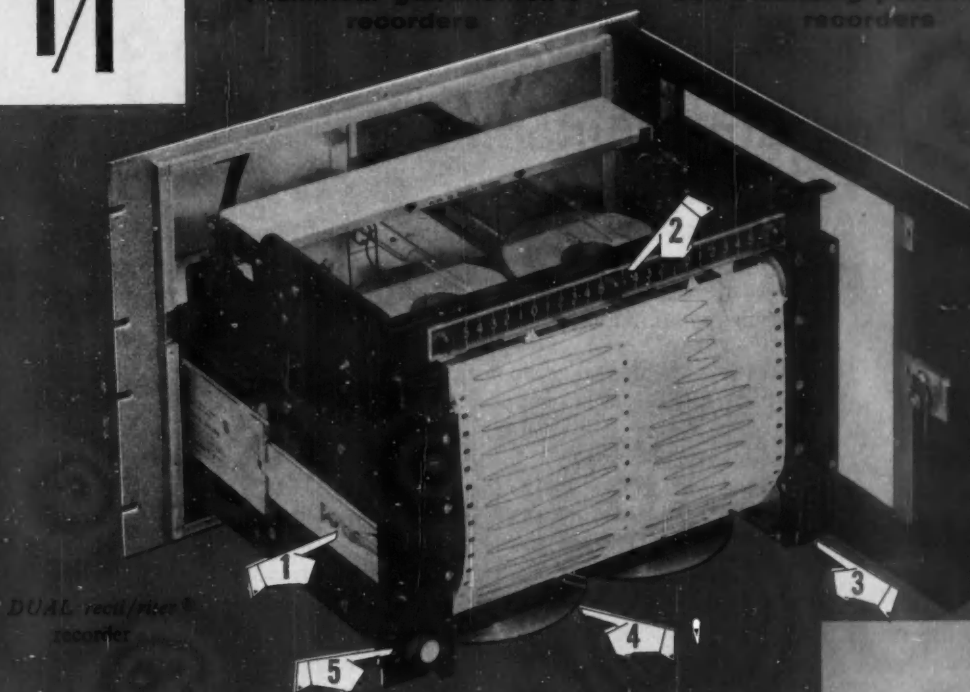
375 CENTRAL AVENUE, DOVER, NEW HAMPSHIRE,

NEW
from
T/I

FLUSH-MOUNTING

recti/riter[®]
millinear galvanometric
recorders

servo/riter[®]
self-balancing potentiometric
recorders

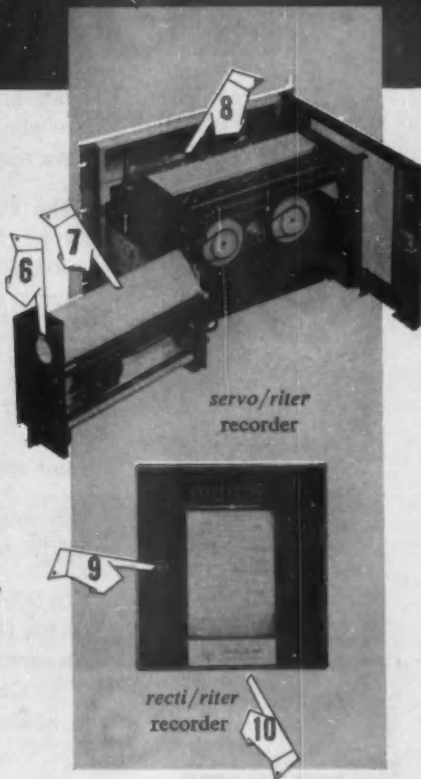


DUAL *recti/riter*[®]
recorder

Exclusive convenience features are added to industry-proved recording performance

The NEW flush-mounting *recti/riter* and *servo/riter* recorders (single, dual, and wide channel) contain these operating conveniences, while retaining the reliability and performance characteristics of the proved TI portable recorders.

1. Chassis rolls out and quickly disconnects for maximum ease of installation, adjustment or servicing.
2. Illuminated scales and pointers maintain high readability regardless of room light level.
3. Fingertip releases for chassis roll-out and swing-open chart carriage.
4. Flexible wide range zero adjustment on *recti/riter* recorder. One-half span of calibrated zero suppression provided in each direction.
5. Four-position switch provides off-on, in./hr., standby, and in./min.
6. Chart speed change gears provide 10 standard speeds.
7. Swing-open chart carriage permits easy paper loading and adjustment. Simply lift up to remove carriage. Advanced design eliminates chart drive gear train lash . . . gives better paper position accuracy.
8. Interior design provides flexibility and adequate space to add special functions with ease.
9. Dust tight case has key lock available for limited access. Dimensions: Single recorders—11½" W., 12½" H., 16" D.; Dual recorders—16¾" W., 12½" H., 16" D.
10. Panel may be easily modified to permit paper feed through bottom of door.



servo/riter
recorder

recti/riter
recorder

Write for complete information . . .

*A Trademark of Texas Instruments

**INSTRUMENTATION
GROUP OF**



**TEXAS INSTRUMENTS
INCORPORATED**

GEOSCIENCES & INSTRUMENTATION DIVISION

3609 BUFFALO SPEEDWAY • HOUSTON 6, TEXAS

CIRCLE 85 ON READER SERVICE CARD

from RCA...

3 NEW Electronic Systems that Advance Industrial Automation

RCA Industrial Electronic Control is industrial dynamism of a higher order—a new electronic control of production operations resulting in a smoother flow through the plant, a bigger yield, and a degree of efficiency never before attainable.

Systems capabilities range from simple automatic monitoring to complete real-time control of a complex automated operation spread over a wide area. There are now three RCA Industrial Electronic Control Systems available:

The RCA-110 Industrial Control Computer System—Specifically designed for industrial applications to provide around-the-clock operating reliability, highest arithmetical speed and lowest cost installation. Solid state design, core and random access drum memory. Computer built for industrial environment.

The RCA-130 Industrial Data Transmission Link—Removes the limitation of distance in an automatic monitoring or control system. Provides reliable on-line, real-time transmission of analog or digital information via wire or radio, one-way or two-way. 100% checked.

The RCA-150 Industrial Data Analysis and Recording System—Provides high-speed, automatic monitoring and analysis of process and production status—plus computational capability for summarizing, averaging, totalizing and linearizing.

These new RCA systems incorporate industrial thinking as advanced as the electronic design of the equipment itself. The new concepts may well be of paramount importance to the future of your business. RCA Industrial Electronic Control Systems are available with Foxboro and other instrumentation.

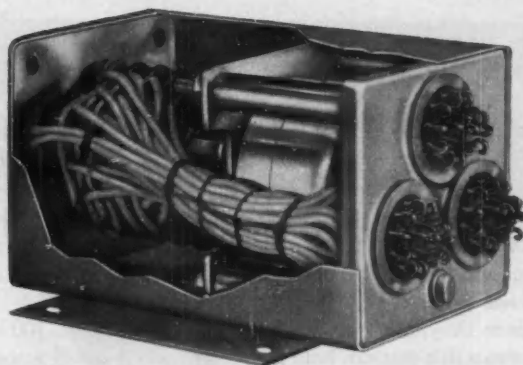
For special industrial control problems, **Custom Systems** can be supplied to fit your exact needs.

To tell you how this modern kind of industrial automation works and the many things it will do, would fill a book. You will want to get the full story in person. Ask your nearest Foxboro representative or write—Industrial Computer Systems Department, Electronic Data Processing Division, Radio Corporation of America, 21 Strathmore Road, Natick, Mass.

**AUTOMATIC
PROCESSING**

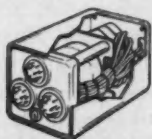


The Most Trusted Name in Electronics
RADIO CORPORATION OF AMERICA

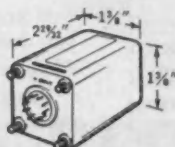


Ledex Hermetically Sealed Rotary Switch

BASIC INFORMATION



Hermetically sealed rotary switch permanently protected from moisture, dust, fumes, corrosion and vibration.



Switch available in 12 throw, 24 throw, 48 throw, 96 throw, 192 throw, 384 throw, 768 throw, 1536 throw, 3072 throw, 6144 throw, 12288 throw, 24576 throw, 49152 throw, 98304 throw, 196608 throw, 393216 throw, 786432 throw, 1572864 throw, 3145728 throw, 6291456 throw, 12582912 throw, 25165824 throw, 50331648 throw, 100663296 throw, 201326592 throw, 402653184 throw, 805306368 throw, 1610612736 throw, 3221225472 throw, 6442450944 throw, 12884901888 throw, 25769803776 throw, 51539607552 throw, 103079215104 throw, 206158430208 throw, 412316860416 throw, 824633720832 throw, 1649267441664 throw, 3298534883328 throw, 6597069766656 throw, 13194139533312 throw, 26388279066624 throw, 52776558133248 throw, 105553116266496 throw, 211106232532992 throw, 422212465065984 throw, 844424930131968 throw, 1688849860263936 throw, 3377699720527872 throw, 6755399441055744 throw, 13510798882111488 throw, 27021597764222976 throw, 54043195528445952 throw, 108086391056891904 throw, 216172782113783808 throw, 432345564227567616 throw, 864691128455135232 throw, 1729382256910270464 throw, 3458764513820540928 throw, 6917529027641081856 throw, 13835058055282163712 throw, 27670116110564327424 throw, 55340232221128654848 throw, 110680464442257309696 throw, 221360928884514619392 throw, 442721857769029238784 throw, 885443715538058477568 throw, 1770887431076116955136 throw, 3541774862152233910272 throw, 7083549724304467820544 throw, 14167099448608935641088 throw, 28334198897217871282176 throw, 56668397794435742564352 throw, 113336795588871485128704 throw, 226673591177742970257408 throw, 453347182355485940514816 throw, 906694364710971881029632 throw, 1813388729421943762059264 throw, 3626777458843887524118528 throw, 7253554917687775048237056 throw, 14507109835375550096474112 throw, 29014219670751100192948224 throw, 58028439341502200385896448 throw, 116056878683004400771792896 throw, 232113757366008801543585792 throw, 464227514732017603087171584 throw, 928455029464035206174343168 throw, 1856910058928070412348686336 throw, 3713820117856140824697372672 throw, 7427640235712281649394745344 throw, 14855280471424563298789490688 throw, 29710560942849126597578981376 throw, 59421121885698253195157962752 throw, 118842243771396506390315925504 throw, 237684487542793012780631851008 throw, 475368975085586025561263702016 throw, 950737950171172051122527404032 throw, 1901475900342344102245054808064 throw, 3802951800684688204490109616128 throw, 7605903601369376408980219232256 throw, 15211807202738752817960438464512 throw, 30423614405477505635920876929024 throw, 60847228810955011271841753858048 throw, 121694457621910022543683507716096 throw, 243388915243820045087367015432192 throw, 486777830487640090174734030864384 throw, 973555660975280180349468061728768 throw, 1947111321950560360698936123457536 throw, 3894222643901120721397872246915072 throw, 7788445287802241442795744493830144 throw, 15576890575604482885591488987660288 throw, 31153781151208965771182977975320576 throw, 62307562302417931542365955950641152 throw, 124615124604835863084731911901282304 throw, 249230249209671726169463823802564608 throw, 498460498419343452338927647605129216 throw, 996920996838686904677855295210258432 throw, 1993841993677373809355710590420516864 throw, 3987683987354747618711421180841033728 throw, 7975367974709495237422842361682067456 throw, 15950735949418990474845684723364134912 throw, 31901471898837980949691369446728269824 throw, 63802943797675961899382738893456539648 throw, 127605887595351923798765477786913079296 throw, 255211775190703847597530955573826158592 throw, 510423550381407695195061911147652317184 throw, 1020847100762815390390123822295304634368 throw, 2041694201525630780780247644590609268736 throw, 4083388403051261561560495289181218537472 throw, 8166776806102523123120990578362437074944 throw, 16333553612205046246241981156724874149888 throw, 32667107224410092492483962313449748299776 throw, 65334214448820184984967924626899496599552 throw, 130668428897640369969935849253798993199104 throw, 261336857795280739939871698507597986398208 throw, 522673715590561479879743397015195972796416 throw, 1045347431181122959759486794030391945592832 throw, 2090694862362245919518973588060783891185664 throw, 4181389724724491839037947176121567782371328 throw, 8362779449448983678075894352243135564742656 throw, 16725558898897967356151788704486271129485312 throw, 33451117797795934712303577408972542258970624 throw, 66902235595591869424607154817945084517941248 throw, 133804471191183738849214309635890169035882496 throw, 267608942382367477698428619271780338071764992 throw, 535217884764734955396857238543560676143529984 throw, 1070435769529469910793714477087121352287059968 throw, 2140871539058939821587428954174242704574119936 throw, 4281743078117879643174857908348485409148239872 throw, 8563486156235759286349715816696970818296479744 throw, 17126972312471518572699431633393941636592959488 throw, 34253944624943037145398863266787883273185918976 throw, 68507889249886074290797726533575766546371837952 throw, 137015778499772148581595453067151533092743675904 throw, 274031556999544297163190906134303066185487351808 throw, 548063113999088594326381812268606132370974703616 throw, 1096126227998177188652763624537212264741949407232 throw, 2192252455996354377305527249074424529483898814464 throw, 4384504911992708754611054498148849058967797628928 throw, 8769009823985417509222108996297698117935595257856 throw, 17538019647970835018444217992595396235871190515712 throw, 35076039295941670036888435985190792471742381031424 throw, 70152078591883340073776871970381584943484762062848 throw, 140304157183766680147553743940763169886969524125696 throw, 280608314367533360295107487881526339773939048251392 throw, 561216628735066720590214975763052679547878096502784 throw, 1122433257470133441180429951526105359095756193005568 throw, 2244866514940266882360859903052210718191512386011136 throw, 4489733029880533764721719806104421436383024772022272 throw, 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throw, 588478287692501321609605258425718726509595822918503235584 throw, 1176956575385002643219210516851437453019191645837006471168 throw, 2353913150770005286438421033702874906038383291674012942336 throw, 4707826301540010572876842067405749812076766583348025884672 throw, 9415652603080021145753684134811499624153533166696051769344 throw, 18831305206160042291507368269622999248307066333392103538688 throw, 37662610412320084583014736539245998496614132666784207077376 throw, 75325220824640169166029473078491996993228265333568414154752 throw, 150650441649280338332058946156983993986456530667136828309504 throw, 301300883298560676664117892313967987972913061334273656619008 throw, 602601766597121353328235784627935975945826122668547313238016 throw, 1205203533194242706656471569255871951891652245337094626476032 throw, 2410407066388485413312943138511743903783304490674189252952064 throw, 4820814132776970826625886277023487807566608981348378505904128 throw, 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44464162267166406613809642883336156615655674111605976585654154120158641781735424 throw, 88928324534332813227619285766672313231311348223211953171308308240317283563470848 throw, 177856649068665626455238571533344626462622696446423906342616616480634567126941696 throw, 355713298137331252910477143066689252925245392892847812685233232961269134253883392 throw, 711426596274662505820954286133378505850490785785695625370466465922538268507766784 throw, 1422853192549325011641908572266757011700981571571391250740932931845076537015533568 throw, 2845706385098650023283817144533514023401963143142782501481865863690153074031067136 throw, 56914127701973



Read this column carefully, because it contains important items of general interest to everyone. Example No. 1: The nine-banded armadillo (*Dasypus novemcinctus*) invariably gives birth to a litter of four young, two male and two female. Example No. 2: The Mincom Model C-100 Instrumentation Recorder/Reproducer is one heck of a good system and we are proud of it. Unlike the armadillo, it does not use its long narrow tongue to snare earthworms and insects—but its input requirements are nearly as relaxed and thereby hangs our tale.

Again differing from *Dasypus novemcinctus*, the Mincom Model C-100 is all-transistorized. This doesn't mean that you can hold it in your hand at a ball game and listen to what you're already seeing, but lots of Dodger fans are Mincom C-100 fans nevertheless. Because the electronics are transistorized, the power input is remarkably low and figures out to about 1/10 of the power usually needed for systems of this type.

Horrible Thought

Applied to *Dasypus* this would mean one earthworm supplying the energy of ten, and in three years would result in the entire country's being covered to a depth of seven feet ten inches in armadillos. Applied to Model C-100 it means about 500 watts input when the tape is coursing over the pucks in full cry, and has resulted in our selling lots of these fine systems.

Neat, Tidy and Cool

There's something so neat and tidy about Mincom's modular building-block construction when it's all transistorized. Appeals to the housewife in all of us, and it's cool, cool, cool. Those agonizing hours when the brass can't make up their minds (known in the industry as "standby time") have lost their sting. Model C-100 doesn't even have any blowers, it's so cool, and that's fine for us little people who do the work: more locker room in the bottom of the rack, even a place to keep our sandwiches. Good for employee relations. Ask your Chairman of the Board to get you a Mincom Model C-100 for your very own.

Everybody Likes Our DC Top Plate

The armadillo's top plate allows him to curl into a hard tight ball with his head and feet tucked out of harm's way. The top plate on a Mincom Model C-100 is even more ingenious because it's entirely powered by DC, which is something the armadillo never heard of. Not yet, anyway.*

The DC top plate is what makes the Model C-100 (and our CM-100, too) all things to all men. When you have all your transport functions powered by DC, you are approaching the moment of truth in instrumentation recording/reproducing. At Mincom and at 3M we say that Research is the Key to Tomorrow; something like the DC top plate is what gives the key at least a quarter-turn.

*As far as we know.

†Did the Romans use fractions? Did they have a decimal system? We're glad you asked that question...

Imagine in your facility a top plate with no nerve-racking mechanical brakes, just smooth easy torque fields that give a stop time under 0.5 seconds at all speeds. If you don't have Dynamic Braking à la Mincom DC Top Plate, your maintenance men are working too hard.

Imagine in your facility a speed control milieu that involves no belt changes. Just look over the brilliantly lighted push buttons on the control panel, pick the speed of your choice (like "30"), think it over and Push. Anyone who can read Arabic numerals (Roman like "XXX" available on special order) can change speeds instantaneously on our exclusive DC top plate. Speeds normally supplied on Model C-100 in ips: III.LXXV, VI, VII.V, XV, XXX atque LX.†

Because our top plate runs on DC converted from just any old AC, you are at last independent of the electric company. You will still have to pay your bill, but power line frequency fluctuations will never bother you again.

Mechanical Simplicity

An armadillo is able to hold his or her breath for long periods and sometimes crosses a stream by crawling along the bottom.



...WHERE RESEARCH IS THE KEY TO TOMORROW



MINCOM DIVISION **MINNESOTA MINING AND MANUFACTURING COMPANY**

2049 SOUTH BARRINGTON AVENUE, LOS ANGELES 25, CALIFORNIA • 425 13th STREET N.W., WASHINGTON 4, D.C.

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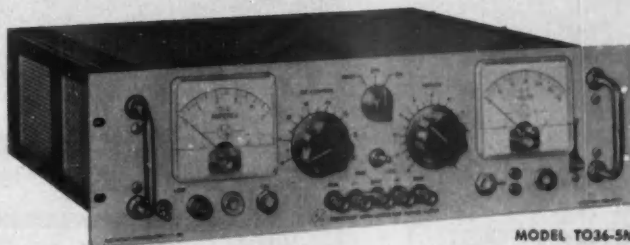
... good reasons why
you can standardize with

*WIDE RANGE MODELS			
D-C OUTPUT		MODEL NUMBER	DIMENSIONS IN INCHES
VOLTS	AMPS		
0-7	0-30	*TO7-30	15 $\frac{3}{4}$ 19 16
0-7	0-15	*TO7-15	8 $\frac{3}{4}$ 19 15
0-7	0-10	*TO7-10	7 19 15
0-7	0-5	*TO7-5	5 $\frac{1}{4}$ 19 15
0-7	0-3	*TO7-3	3 $\frac{1}{2}$ 19 12 $\frac{1}{2}$
0-14	0-20	*TO14-20	15 $\frac{3}{4}$ 19 16
0-14	0-10	*TO14-10	8 $\frac{3}{4}$ 19 15
0-14	0-5	*TO14-5	7 19 15
0-14	0-3	*TO14-3	5 $\frac{1}{4}$ 19 15
0-32	0-30	TO32-30	15 $\frac{3}{4}$ 19 16
0-32	0-15	TO32-15	8 $\frac{3}{4}$ 19 15
0-32	0-10	TO32-10	7 19 15
0-32	0-5	TO32-5	5 $\frac{1}{4}$ 19 15
0-32	0-3	TO32-3	3 $\frac{1}{2}$ 19 12 $\frac{1}{2}$
0-36	0-30	TO36-30	15 $\frac{3}{4}$ 19 16
0-36	0-15	TO36-15	8 $\frac{3}{4}$ 19 15
0-36	0-10	TO36-10	7 19 15
0-36	0-5	TO36-5	5 $\frac{1}{4}$ 19 15
0-36	0-3	TO36-3	3 $\frac{1}{2}$ 19 12 $\frac{1}{2}$
0-60	0-15	TO60-15	15 $\frac{3}{4}$ 19 15
0-60	0-7.5	TO60-7.5	8 $\frac{3}{4}$ 19 15
0-60	0-5	TO60-5	7 19 15
0-60	0-2.5	TO60-2.5	5 $\frac{1}{4}$ 19 15
0-60	0-1.5	TO60-1.5	3 $\frac{1}{2}$ 19 12 $\frac{1}{2}$

*MODELS MARKED WITH AN ASTERISK ARE PROGRAMMABLE.

†NARROW RANGE MODELS			
5-7.5	0-30	T6-30	15 $\frac{3}{4}$ 19 16
5-7.5	0-15	T6-15	8 $\frac{3}{4}$ 19 15
5-7.5	0-10	T6-10	7 19 15
5-7.5	0-5	T6-5	5 $\frac{1}{4}$ 19 15
5-7.5	0-3	T6-3	3 $\frac{1}{2}$ 19 12 $\frac{1}{2}$
7-11	0-15	T9-15	8 $\frac{3}{4}$ 19 15
7-11	0-10	T9-10	7 19 15
7-11	0-5	T9-5	5 $\frac{1}{4}$ 19 15
11-14	0-30	T12-30	15 $\frac{3}{4}$ 19 16
11-14	0-15	T12-15	8 $\frac{3}{4}$ 19 15
11-14	0-10	T12-10	7 19 15
11-14	0-5	T12-5	5 $\frac{1}{4}$ 19 15
11-14	0-3	T12-3	3 $\frac{1}{2}$ 19 12 $\frac{1}{2}$
14-17	0-15	T16-15	8 $\frac{3}{4}$ 19 15
14-17	0-10	T16-10	7 19 15
14-17	0-5	T16-5	5 $\frac{1}{4}$ 19 15
17-20	0-15	T19-15	8 $\frac{3}{4}$ 19 15
17-20	0-10	T19-10	7 19 15
17-20	0-5	T19-5	5 $\frac{1}{4}$ 19 15
20-23	0-15	T22-15	8 $\frac{3}{4}$ 19 15
20-23	0-10	T22-10	7 19 15
20-23	0-5	T22-5	5 $\frac{1}{4}$ 19 15
22.5-27	0-30	T25-30	15 $\frac{3}{4}$ 19 16
22.5-27	0-12	T25-12	8 $\frac{3}{4}$ 19 15
22.5-27	0-10	T25-10	7 19 15
22.5-27	0-5	T25-5	5 $\frac{1}{4}$ 19 15
22.5-27	0-3	T25-3	3 $\frac{1}{2}$ 19 12 $\frac{1}{2}$
25-31	0-30	T28-30	15 $\frac{3}{4}$ 19 16
25-31	0-12	T28-12	8 $\frac{3}{4}$ 19 15
25-31	0-10	T28-10	7 19 15
25-31	0-4.5	T28-4.5	5 $\frac{1}{4}$ 19 15
25-31	0-3	T28-3	3 $\frac{1}{2}$ 19 12 $\frac{1}{2}$
31-33.5	0-30	T32-30	15 $\frac{3}{4}$ 19 16
31-33.5	0-12	T32-12	8 $\frac{3}{4}$ 19 15
31-33.5	0-10	T32-10	7 19 15
31-33.5	0-5	T32-5	5 $\frac{1}{4}$ 19 15
31-33.5	0-3	T32-3	3 $\frac{1}{2}$ 19 12 $\frac{1}{2}$
33.5-36	0-30	T35-30	15 $\frac{3}{4}$ 19 16
33.5-36	0-12	T35-12	8 $\frac{3}{4}$ 19 15
33.5-36	0-10	T35-10	7 19 15
33.5-36	0-5	T35-5	5 $\frac{1}{4}$ 19 15
33.5-36	0-3	T35-3	3 $\frac{1}{2}$ 19 12 $\frac{1}{2}$

†ALL NARROW RANGE MODELS ARE PROGRAMMABLE.



MODEL TO36-5M

REGATRAN[®] SEMICONDUCTOR POWER SUPPLIES

SPECIFICATIONS

*REGULATION: 0.03% or 0.01 V from no load to full load and 105 to 125 V line. (0.1% or 0.01 V for 3-amp models.)

RIPPLE: Less than 1 millivolt rms.

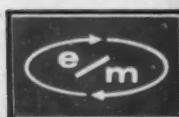
INPUT: 105 V to 125 V, 50 to 60 cps.

CIRCUIT PROTECTION: Four-year field-tested electronic and electrical circuit protection.

MOUNTING: Rack and table.

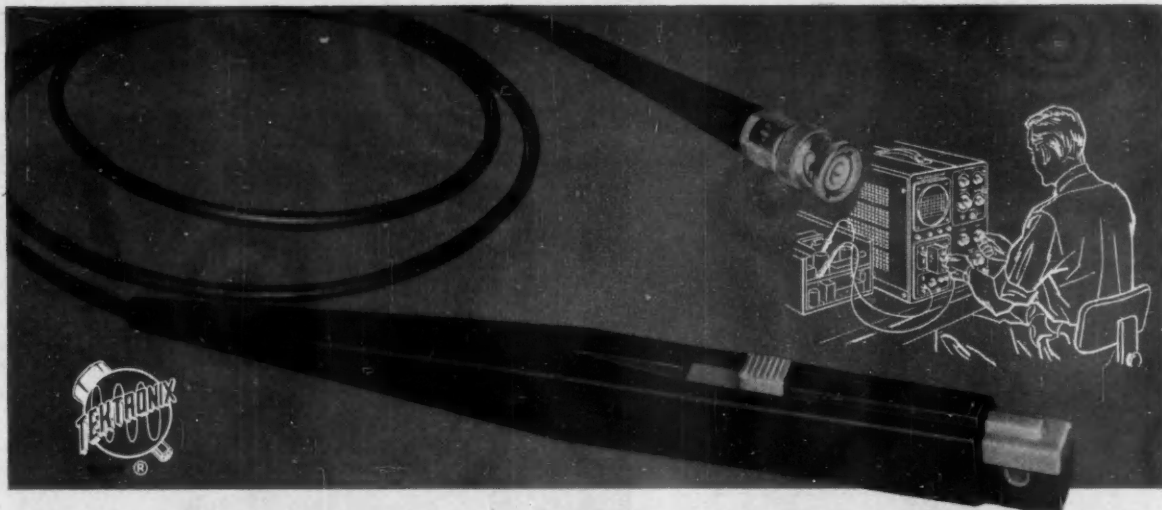
*0.01% or 0.003 V regulation available on special order.

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NEW HIGH-FREQUENCY CURRENT PROBE

for Your Tektronix Oscilloscope

The P6016 AC Current Probe and Type 131 Amplifier constitute a current-detecting system for use with your Tektronix Oscilloscope. This system provides accurate displays for observation and measurement of current waveforms. Current range extends from less than one milliamp to 10 amps. Passband, with a 30-mc oscilloscope, is 50 cps to approximately 17 mc.

A second system comprises the P6016 AC Current Probe with a Passive Termination. Although less versatile, this system provides for observation and measurement of current waveforms at frequencies to approximately 20 mc with a 30-mc oscilloscope.

Long narrow shape and convenient thumb control make the P6016 easy to use. Just place probe slot over conductor and close slide with thumb—no direct electrical connection is required. Wiping action keeps core surfaces clean. Loading introduced is so light that it can almost always be disregarded.

CAREER OPPORTUNITIES now exist at Tektronix in the following fields: Instrument design, Circuit design and engineering, Cathode ray tubes, Electron physics, Solid state and semi-conductor devices. For information write to Irving Smith, Professional Placement.

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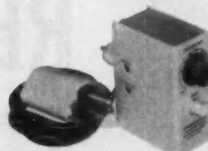
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SPECIFICATIONS P6016 and TYPE 131 SYSTEM



Sensitivity with 50 mv/div Oscilloscope Input:

1 ma/div basic sensitivity. Ten-position switch provides calibrated steps of 1, 2, 5, 10, 20, and 50 ma/div... 0.1, 0.2, 0.5, and 1 amp/div, accurate within 3%. Continuous uncalibrated adjustment is possible by using variable control on the oscilloscope.

Noise:

Equivalent to a 100-microampere peak-to-peak input signal.

Risetime (with Type K or L Plug-In Unit in a Type 540-Series Oscilloscope):

20 nanoseconds (approximately 17 mc at 3 db down).

Low-frequency Response:

50 cps at 3 db down.

Maximum Current Rating:

10 amperes peak-to-peak.

Power Requirements:

105-125 volts ac, approximately 1/2 watt at 117 v.

P6016 and PASSIVE TERMINATION SYSTEM

Sensitivity:

Either 2 or 10 milliamperes per millivolt of oscilloscope sensitivity, accurate within 3%.

Risetime (with Type K or L Plug-In Unit in a Type 540-Series Oscilloscope):

16 nanoseconds (approximately 20 mc at 3 db down).

Low-Frequency Response:

At 2 ma/mv—about 850 cps at 3 db down (5% tilt of 14 microsecond square pulse).



At 10 ma/mv—about 230 cps at 3 db down (5% tilt of 55 microsecond square pulse).

Maximum Current Rating:

15 amperes peak-to-peak.

COMMON TO BOTH SYSTEMS

Direct Current Saturation

Threshold:

1/2 ampere.

Maximum Breakdown Voltage

Rating:

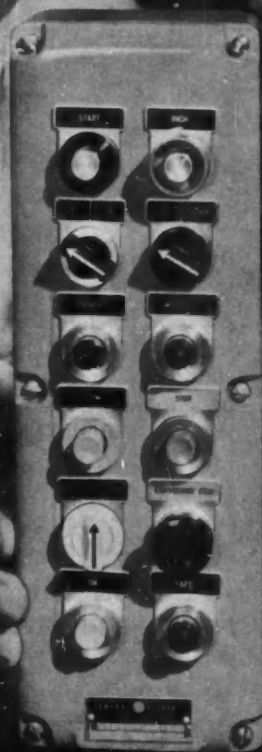
600 volts, with thumb slide closed.

Insertion Impedance:

About 0.005 ohms or less in series with conductor under test, and typically about 1.5 picofarads between the conductor and probe case.

Price, TYPE P6016 and TYPE 131 SYSTEM	\$235
TYPE P6016 and PASSIVE TERMINATION SYSTEM	\$ 90
Type P6016, purchased separately	\$ 75
Type 131, purchased separately	\$160
Passive Termination, purchased separately	\$ 15
f.o.b. factory	

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New General Electric miniature push buttons cut panel space 40%. Twelve-unit miniature station (left) is shorter, narrower than twelve-unit heavy-duty station (above).

First industrial miniature oil-tight pushbutton line allows design innovations on your equipment

For the first time, control panels and industrial machines can be built with *miniature* oil- and dust-tight pushbutton units, designed specifically for the reliable operation required in industrial applications.

With the new General Electric CR-104 miniature oil-tight pushbutton line, space can be reduced 40%. And, you can get the operating and functional units presently available in heavy-duty oil-tight forms. Color coding is available in both operators and rings to provide

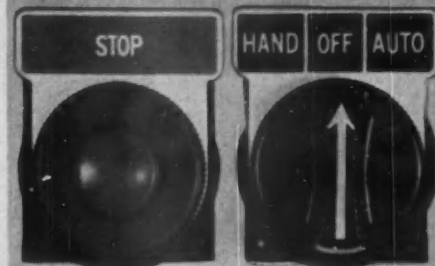
greater flexibility in color combinations, and the attractive appearance enhances the design of your machines. Units, illuminated forms, pendent stations, and enclosures to accommodate from four to 42 units are available now.

For more information on this outstanding new development in control—and the “measurable advantages” it offers—contact your nearby G-E Apparatus Sales Office, or write for bulletin GEA-7127, General Electric Co., Schenectady 5, N. Y.

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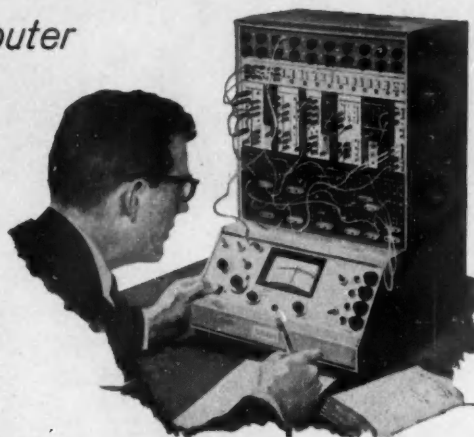
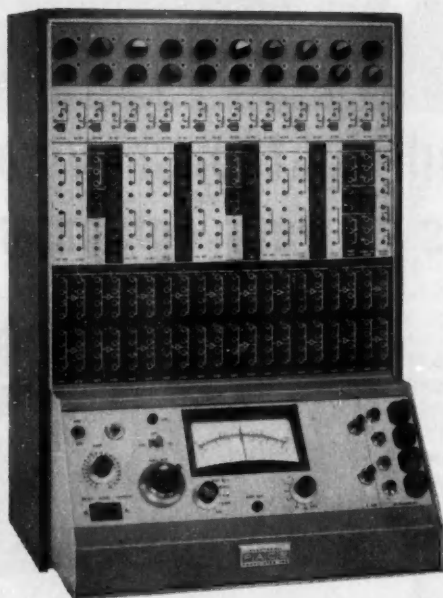
Actual size G-E miniature oil-tight pushbutton and selector switch units.

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EAI Transistorized Analog Computer

A WIDE RANGE OF SOLUTIONS AT DESIGN ENGINEERS' FINGERTIPS...

PACE® TR-10, the first all transistorized desktop analog computer, puts proven high-speed computation right where it's needed — on the desks of busy engineers. With this easy-to-use simulator, you can quickly solve many problems without waiting for scheduled access to large-computing systems. Though compact in size, the TR-10 is a full-fledged analog computer capable of providing solutions to a wide range of design problems. Up to 20 amplifiers, plus linear and non-linear computing components are contained in one compact cabinet with no external racks. The TR-10 permits rapid evaluation of different design approaches. It demonstrates the performance of a conceptual or drawing-board design prior to construction. Thus it saves time and money normally required for multiple test models with cut-and-try engineering.



Here's How The TR-10 Saves Engineering Time

The TR-10 is especially useful in solving problems in such diverse areas as servo-system design, heat flow, chemical reaction analyses, suspension systems studies and many other problems involving dynamic conditions. Fast answers to problems posed by new design ideas immediately determine feasibility of projects. With the TR-10, engineers can explore new ideas as they occur — concentrate valuable time on the most promising area of study.

(Applications notes are available describing typical problem solutions.)

How Do You Use The TR-10?

First—Represent in equation form the physical system to be studied.

Second—Select through a simple computer diagram the computing components required to perform the calculation (programming).

Third—Interconnect these components on the computer (problem patching) and set problem parameters with adjustable controls.

Fourth—Run the problem with results presented graphically on an accessory recorder or oscilloscope. You now have an electronic analog model of the physical system under study. You can manipulate design parameters quickly, running comparative solutions without becoming involved in repeated calculations. With the TR-10 you can rapidly develop truly optimum designs.

For complete details of TR-10, write for free copy of Bulletin CC821-A.

◀ **PACE TR-10** Analog Computer, including components for addition, subtraction, multiplication, division, integration and generation of powers, roots, logs, antilogs and arbitrary functions.

EAI

ELECTRONIC ASSOCIATES, INC. Long Branch, New Jersey



Eenie Meenie Minie Moe— Which Numerical Control Will Go?

The machine tool industry, notoriously hidebound and conservative, has embraced numerical-control with the fervor of a religious convert. But the enthusiasm of machine tool builders has raised a perplexing problem for potential users and buyers of numerically controlled machine tools: which to specify?

Machine tool builders are leaving it up to customers to decide which positioning control to ask for. And the tool builders have adopted a completely neutral attitude. Said one, "We've designed our machine tools so they can be controlled by a lot of numerical control systems. We will give you a package with any control you want." That means it is up to the customer to pick the one best suited for his operation.

Control makers are worried about the trend too. One pointed out that previously the control builders sold their wares through the machine tool builder. A sales manager of a major control company explained to CtE how it worked, "We had convinced a number of machine tool builders to use our magnetic starters and variable speed drives, and they standardized on them. When a customer bought one of these tools, he automatically got our control. But things are different with numerical control. First we have to sell the builder on the fact that we have a positioning system and then we have to go to the end user with the hard sell".

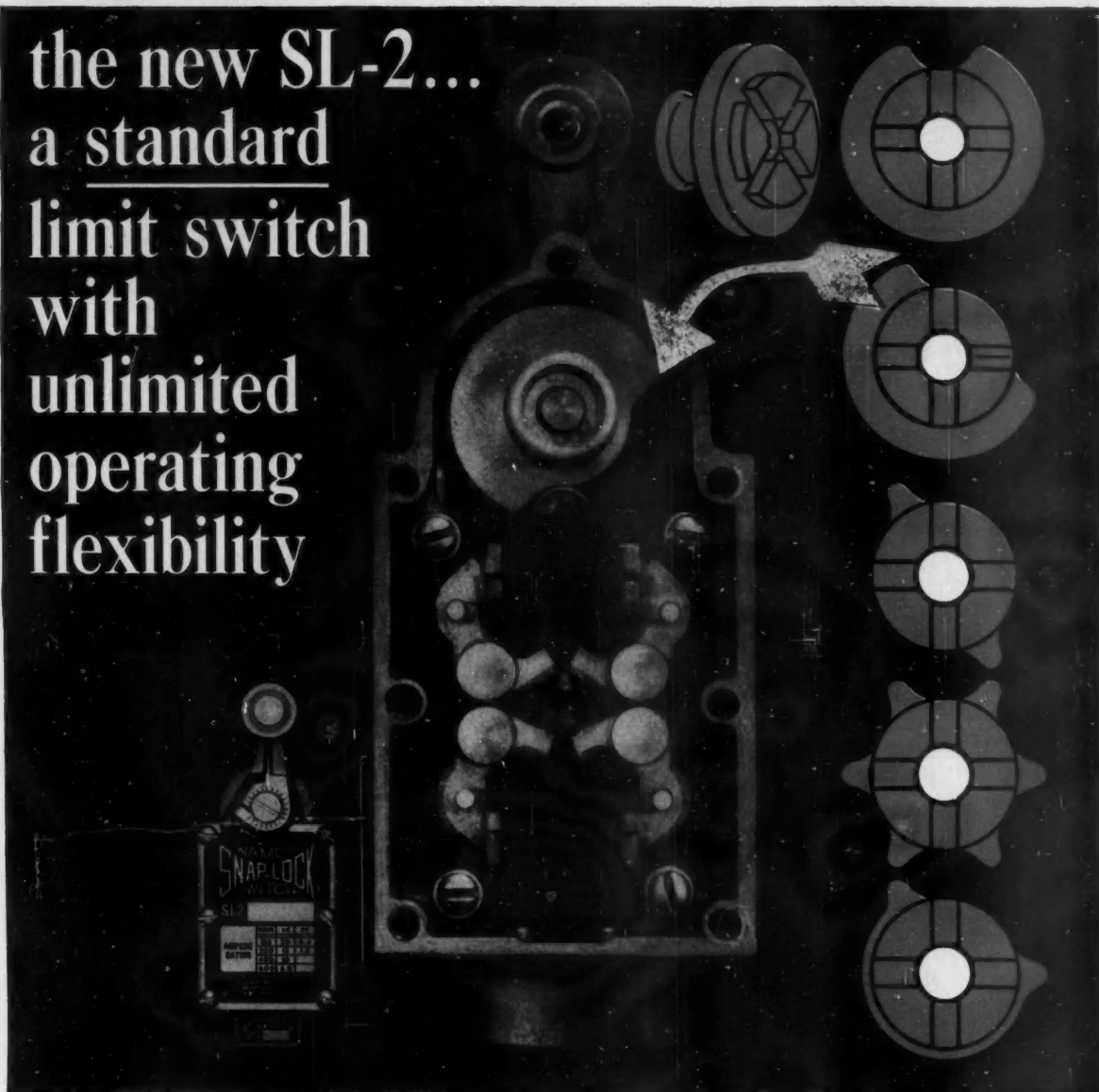
In their conversion to numerical control, machine tool builders have made tools available with the broadest range of control systems. A purchaser can choose an all-electrical system (no electronic equipment) like the one Micro-Path has built for a single spindle drill press made by Sibley Machine and Foundry Co. Or a firm believer in fluid drives can purchase a pneumatic-hydraulic point-to-point positioning system built by Moog Servo-Controls, Inc. for a Burg turret drill, and costing less than \$9,000. A user can also choose a pneumatic-electronic-hydraulic combination that Sperry has built to control a new Wiedemann 15-ton turret punch press or an all-electronic control like ones made by General Electric, Bendix, Norden, Thompson Ramo Wooldridge, Westinghouse, Minneapolis-Honeywell, Hughes, Reliance, Square D, or Wang Laboratories.

Probably the best example of what is involved is the turret drill press made by the Burg Tool Mfg. Co. A Burg spokesman

Customer's choice

Big menu

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Tailor limit switch performance to your specific job with NAMCO'S *standard* SL-2. This "machine life" limit switch features a standard cam blank which can be cut into a wide variety of configurations to meet any application. These interchangeable cams provide positive control of contact sequence; let you match switch operation to your specific job. Ruggedly built, oil-tight and moisture-proof, the SL-2 provides dependable, accurate performance that meets your most precise requirements.

Now available for low-current, high-shock, excessive-vibration applications...the SLS-2... with full-wiping, self-cleaning sliding contacts that insure "everytime" operation under conditions that spell machine downtime for other limit switches.

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said the company will supply any of seven different control systems, but the buyer must make the choice.

Another example is the Wiedematic 15, the new 15-ton turret punch press introduced by Wiedmann Machine Co. It comes with either a GE Mark II control system or a Sperry two-D control. Regardless of which control is used, the delivered machine costs the same and has the same capability. The user has to decide between Sperry's single panel with a small control pedestal and GE's twin racks of electronics and its big operating console. However there is more to the choice than just size. Because the Sperry unit has a block reader to convert big chunks of input data into control instructions, the system needs fewer components. The GE system has a sequential reader and buffer memory to store enough input data to direct the press at its specified piercing rate of 60 holes per min. With the block reader, there is a chance of losing all the input data if something goes amiss at the reader; the GE system is less likely to have such an outage. Such considerations mean that the buyer's choice is not an easy one.

Another dilemma

Because of machine tool builders' bashfulness, at least one control company, Hughes Aircraft, is crashing out on its own. Hughes bought three Brown and Sharpe turret drills, outfitted the machine with Hughes numerical controls, and then sold the packages to metalworking customers. Most control companies, however, shudder at this method of selling.

On their own

To simplify selling, some control makers are trying to convince machine tool builders to market a special model married to one control system. For example, Diehl Manufacturing Co., a division of Singer, worked closely with Wade, a lathe manufacturer, to develop a numerically controlled turning lathe. And Diehl expects to have sales of over 100 systems within the next two months as a result.

So, prospective buyers of numerically controlled machines face these alternatives:

More choices

- Some machines have control systems built by the machine tool builder. Jones and Lamson, Cincinnati Milling, DeVlieg Machine Co., Fosdick Machine Tool Co., Carlton Machine Tool Co., Natco, and Warner and Swasey—all make their own control systems.

- Some machines have a specific control system married to them.

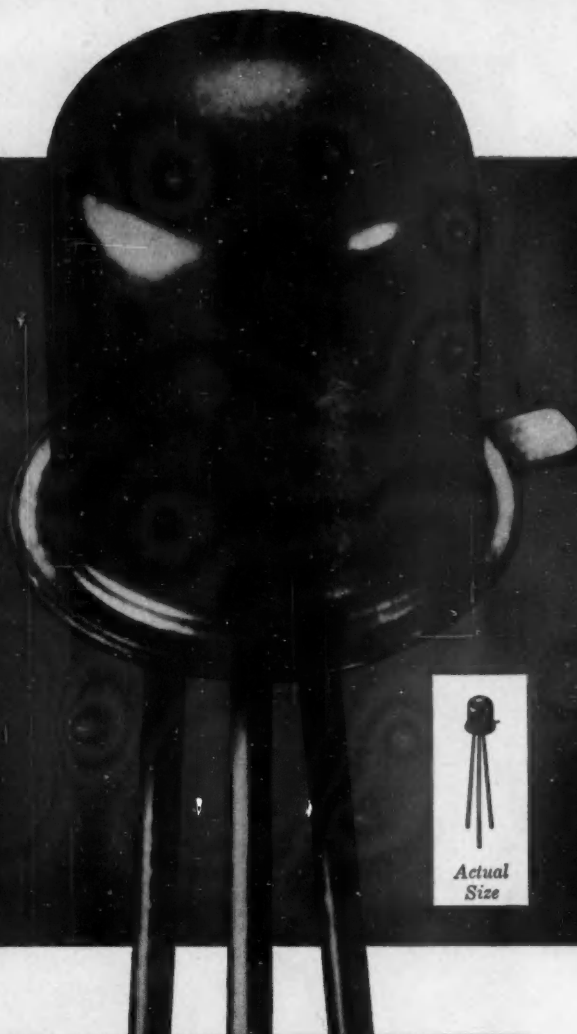
- The bulk of the machines can be bought with a variety of control systems, depending on the buyer's preference.



PHILCO ANNOUNCES

NEW HIGH-SPEED
SWITCHING TRANSISTOR
IN TO-18 CASE...

MASS PRODUCED with
ABSOLUTE UNIFORMITY
to the **TIGHTEST SPECS**
IN THE INDUSTRY



This new Philco Germanium MADT is specifically designed for high-speed switching applications and is the ideal NOR logic transistor. The MADT Precision-Etch* process makes it possible to manufacture the 2N779 with the tightest control of parameters of any transistor in the entire industry. This extreme uniformity greatly simplifies the design of high performance, low cost switching circuits. For complete data and information, write Dept. CE1060.

*Trademark Philco Corp.

MADT 2N779

ABSOLUTE MAXIMUM RATINGS

Storage Temperature -65°C to $+100^{\circ}\text{C}$
Collector Voltage, V_{CE} -15 volts
Total Device Dissipation at 25°C 60 mW

ELECTRICAL CHARACTERISTICS ($T=25^{\circ}\text{C}$)

	Min.	Typ.	Max.	
Static Characteristics				
Collector Cutoff Current, I_{CBO} ($V_{CE} = -5\text{v}$)		1.0	3	μA
DC Current Amplification Factor, h_{FE} ($V_{CE} = -0.5\text{v}$, $I_C = -10\text{ ma}$)	50	90	290	
Base Voltage, V_{BE} ($I_C = -10\text{ ma}$, $I_B = -0.5\text{ ma}$)	0.29	0.33	0.36	volt
Collector Saturation Voltage, $V_{CE(SAT)}$ ($I_C = -10\text{ ma}$, $I_B = -0.5\text{ ma}$)	.09	0.12	0.16	volt
High Frequency Characteristics				
Output Capacitance, C_{ob} ($V_{CE} = -3\text{v}$, $I_C = 0$, $f = 4\text{ mc}$)		1.9	2.5	μmf
Input Capacitance, C_{ib} ($V_{BE} = -1\text{v}$, $I_C = 0$, $f = 4\text{ mc}$)		6.0	10	μmf
Gain Bandwidth Product, f_T ($V_{CE} = -5\text{v}$, $I_C = 7\text{ ma}$)	320	450		mc
Switching Characteristics				
Rise Time, t_r ($\beta_C = 10$)		13	18	μsec
Base Storage Factor, K'		39	50	μsec
Fall Time, t_f ($\beta_{CO} = 10$)		10	18	μsec

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CIRCLE 96 ON READER SERVICE CARD



The Pace Quickens

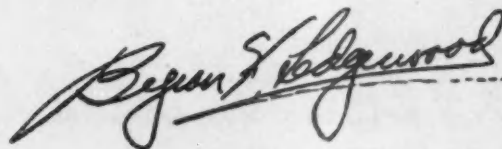
Since CONTROL ENGINEERING started publishing six years ago it has been a favorite game of the editors to guess how long it would take the brand new techniques and developments just appearing on the horizon to turn into successfully operating systems on the factory floor. Invariably we have overestimated the time delay, and practical equipment has been developed, shaken down, and put to work in a much shorter period than we had guessed. While accused of "blue-sky" thinking, it appears that our estimates were actually conservative if anything.

A glance back through the pages of the magazine shows the transition from conjecture through "how to" to actual case studies of on-line equipment. In March 1955 Carl A. Vossberg proposed advanced approaches to rolling mill control in "New Techniques in Automatic Mill Control". Although thought of as radical at the time, several mills are now operating under computer programming and on-line control: "Digital Computer Runs Hot Plate Mill", January 1960 and "Bringing the Hot Strip Mill Under Automatic Control", September 1960 describe two advanced systems that far surpass anything proposed by Vossberg in 1955—and in a period of five short years.

An early look at production monitoring and control was provided by E. D. Lucas, Jr., in "Automatic Production Inventory Control", September 1955. Today simple computer monitoring of production and inventory are commonplace, and more complex money-making systems such as detailed by A. O. Smith in "Manufacturing Control With a 705", May 1960 and by Lockheed Aircraft in "Computer Keeps Tabs on Work in Process", September 1960 are the order of the day.

When the special September 1957 issue of CONTROL ENGINEERING was totally devoted to computing-control, few believed that in a period of three years many computers would be sold for on-line control of processes. Goodrich's experiences, covered in "Goodrich Eases into Computing-Control", April 1960, and the Monsanto story "Closed-Loop Computer Control in Luling" to be published in November 1960 show dramatic progress. And the great number of numerical control systems displayed at the Machine Tool Show and previewed in "A Status Report on Control of Metalworking Machinery", September 1960 show the equally dramatic progress of machine controls.

Certain things are clear: all of the new systems have a high computing and information handling ability. More sophisticated man-machine relationships, learning machines, and adaptive controllers are now on the horizon. But the problem of telling when these will be earning money for control users is no easier than it was a few years ago. All that's certain is that the pace is faster than ever.



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the formation of
AEROSPACE
CORPORATION
a new and vital force
engaged in
accelerating
the advancement
of space science
and technology

Aerospace Corporation has been brought into being to serve the United States government by concentrating the full resources of modern science and technology on rapidly achieving those advances in space systems indispensable to the national security.

The corporation is non-profit, will share the findings of its research and laboratory experiments with all appropriate organizations involved in the government's missile-space program, and is not organized for manufacturing purposes.

The immediate responsibility of Aerospace Corporation is to aid the United States Air Force in bringing about the best possible ballistic missiles and military space systems on a continuing basis and within the shortest possible time.

In addition, it may furnish the National Aeronautics and Space Administration and other governmental agencies appropriate services whenever its participation in space exploration and related activities is desired.

THE MISSION of Aerospace Corporation, according to the Secretary of the Air Force, encompasses "the field of ballistic missile and space programs. Within this complete area, it has the responsibility for advanced systems analysis, research and experimentation, and initial systems engineering. It will also exercise such general technical supervision of ballistic systems as is appropriate. In special cases, and with the consent of the Secretary of the Air Force, Aerospace Corporation may assume broader responsibility for an Air Force military system."

The new corporation also provides support to the Air Force in its effort to achieve maximum interchange of knowledge with other military services and among universities, research foundations, and the scientific community in general.

THE FUNCTIONS of Aerospace Corporation in carrying out its

responsibilities for the Air Force's missile-space programs include the performance of a wide range of scientific, technical, and administrative tasks.

The corporation will conduct extensive laboratory and field activities aimed at advancing the state-of-the-art and will augment these research and development activities by coordination with industry, universities, laboratories, and other agencies. It is intended that this combined effort will push forward the boundaries of technology on a broad front to fulfill military and other national requirements.

Aerospace Corporation will study the application of the advancing technology to military weapons, support systems, and other systems serving the national need. These studies will culminate in preliminary design and in recommendations for development programs.

Aerospace Corporation will then assist the Air Force or other appropriate government agencies in establishing space programs and in bringing the force of American industry to bear in carrying them out. Once development is initiated, Aerospace Corporation will assume responsibilities for the broad technical aspects of these new programs through their critical phases.

THE FACILITIES of Aerospace Corporation include a research and development center located near the Los Angeles International Airport and within easy reach of several attractive residential communities.

They constitute a modern administrative, scientific, and engineering headquarters which house some of the world's most advanced instrumentation and experimental apparatus.

In addition, the operations of Aerospace Corporation will be directly supported around the globe by a vast array of resources created by the government over the past six years.

These will include: The Atlantic Missile Range in Florida; The Pacific Missile Range in California; The Rocket Engine Test Site at Edwards Air Force Base in California; and numerous other missile test facilities sponsored by the government in cooperation with private industry.

THE PEOPLE who make up Aerospace Corporation have been selected from industry, universities, and government. They constitute a cross-section of highly-developed engineering and scientific skills in the missile and space fields.

Extensive recruiting will continue as the new corporation assumes more and more responsibility. From the outset, the corporation is built on a foundation of proven scientific competence, imagination, and objectivity.

THE OPPORTUNITY awaiting those scientists and engineers who qualify to join Aerospace Corporation is equalled only by the magnitude of the corporation's mission — magnitude mirrored by the highly advanced nature of the programs in which Aerospace Corporation is engaged.

Typical systems projects include: advanced ballistic missiles; advanced military space boosters; recoverable boosters and satellites; space defense systems; early-warning satellites; reconnaissance satellites; communications satellites; and manned satellite systems.

Typical research programs concern: nuclear propulsion; astrodynamics; magnetohydrodynamics; inertial elements; millimeter waves; hypersonics; combustion kinetics; and materials research.

Those capable of contributing to state-of-the-art advances in these and related areas are invited to consider the advantages of becoming a part of the new Aerospace Corporation. Their resumes should be directed to: Mr. James M. Benning, P. O. Box 95081-H, Los Angeles 45, California.

AEROSPACE CORPORATION



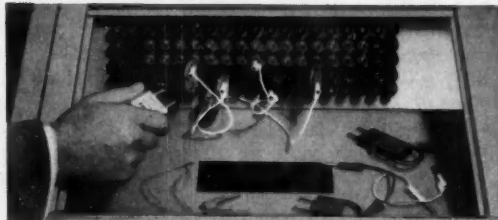
2400 East El Segundo Boulevard • El Segundo, California

Did you ever use a computer as versatile as the **DONNER 3100?**



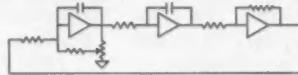
The Donner 3100 isn't for people who merely wish to push buttons. It is a medium sized, high accuracy computer, simple to operate, but designed so it doesn't horsecollar the operator. In its class (20 to 100 amplifiers) it is the most versatile analog computer. Two big reasons for this are the 3100's *uncommitted amplifiers* and its *simulation board*, an auxiliary patchbay electrically connected to the main removable problem board. Here's what they do:

Uncommitted Amplifiers. The 3100's amplifiers are not already wired as summers or integrators. The operator patches his resistors and capacitors to the amplifier. Obviously, he is not limited to using computing components with fixed values. If he wants to use only two components per amplifier, all the rest are free. Depending upon your needs, the 3100 can be supplied with up to 50 amplifiers per console and two or more consoles may be slaved.

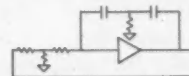


The Simulation Board. Here the operator can plug in a wide variety of components—resistors, capacitors, pots and diodes. He can synthesize (a) complex input and feedback networks for amplifiers, (b) complex resis-

tor-diode limiting circuits and (c) resistor-capacitor-inductor filter networks. Programming these circuits on the simulation board is far simpler and saves amplifiers. For example, a mass-spring system is oscillatory and usually needs three amplifiers to simulate it:



But this clever little circuit does the same thing:



You see, we have eliminated two amplifiers by using the simulation board.

Speaking of economy, **\$13,995** buys a Donner 3100 with 30 stabilized amplifiers and 55 potentiometers. A full line of nonlinear and accessory equipment is available. Free instruction on computer theory and operation is included.

Get More Facts — Contact your Donner engineering representative for Data File 310, or write directly to Dept 21.

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PNPN Switches— Diodes and Triodes

What They Are and How They Work

Semiconductor switches are only beginning to come into their own, and static relays and power contactors will soon be commonplace in reliable control systems. Here an expert discusses the most important semiconductor switching device, the PNPN switch—starting with the original diode form and including the triode known as the controlled rectifier.

J. M. GOLDEY
Bell Telephone Laboratories

PNPN diodes or triodes are four-region semiconductor devices with bistable voltage-current characteristics which make them extremely useful as static switches. They have very high "off" to "on" impedance ratios, dissipate little power, and switch very quickly. High power PNPN triodes are available to switch 50 amp dc (500 amp pulse) at as high as 200 volts. Another version can handle 16 amp dc (160 amp pulse) at 400 volts. Medium and low power high speed triodes are available with breakover voltages up to 200 volts and switching times in tenths of microseconds. A variety of diodes are on the market to handle 20 amp on a pulse basis, switch in 0.1 microsec, and offer controlled breakover voltages between 20 and 200 volts.

Figure 1 is a typical voltage-current characteristic for a PNPN diode. Very little current flows in the forward direction (external P region biased positively with respect to the external N region) until the forward breakover voltage BV_F is reached. Region I is therefore a region of very high dc impedance. The impedance in region I is lowered at high frequencies by the PN junction capacitance which may be as low as a few micromicrofarads in small diodes.

Region II, between BV_F and the hold current I_h , is a region of high negative resistance and connects the two stable states.

For currents greater than the hold current (region III), the diode presents a very low impedance. The PNPN device is a regenerative switch and holds itself in low impedance "on" state so long as the current is greater than the hold current I_h .

Due to the regenerative nature of PNPN devices, the current flows uniformly over the entire area, and more power can be handled than in transistors

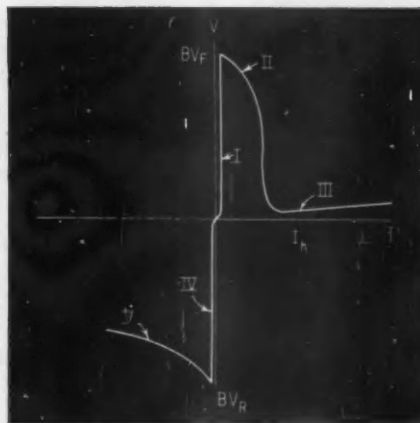


FIG. 1. Static V-I characteristics of two-terminal PNPN switch. Region I is of high impedance and is connected by a negative resistance, region II, to the low impedance region III. The breakover voltage BV_F and the hold current I_h are designable. Reverse blocking is present in many types of PNPN switches, as illustrated in the third quadrant.

where the current is confined to a small part of the emitter. The impedance in region III is similar to that of a forward-biased PN diode and includes a voltage drop equal to that of a single PN junction (about 0.7 volt in silicon) plus a small ohmic term (as low as 0.001 ohm in large power units).

In the reverse direction (external N region positive with respect to external P region) region IV shows a high impedance with characteristics similar to those of region I for voltages lower than the reverse breakover voltage BV_R . BV_R may be much greater than or less than BV_F , depending upon the design. Sometimes BV_R is made zero.

Region V shows negative followed by positive

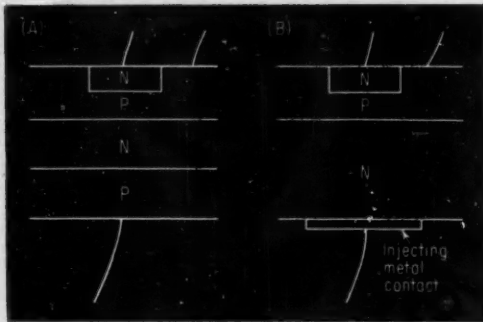


FIG. 3. A—PNPN diode schematic. B—PNPN structure can be considered as an NPN and a PNP transistor combination. C—PNPN material shown as three single-junction diodes in series, a good representation of the device before switching.

resistance in the reverse direction. When BV_R is zero, the resistance of region V is positive.

PNPN structures

Various techniques have been used to build PNPN switches. They include many combinations of grown, alloyed, diffused, and injecting metal contacts to form the junctions. Figure 2 shows the two basic variations. In Figure 2A all junctions are either grown, alloyed, or diffused, and a high BV_R can be achieved. In 2B the bottom emitter is an injecting metal contact, so the diode has little or no reverse breakover voltage.

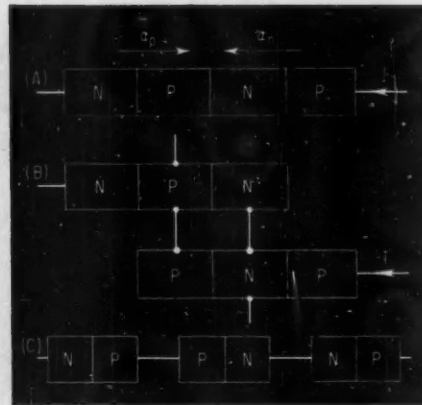
Mechanism of PNPN switching

The PNPN diode, see Figure 3, may be considered as two transistors, a PNP and an NPN, with a common collector. As a matter of fact, two such transistors connected as shown in Figure 3B will act the same as the PNPN structure (Ref. 1). The switching action of the structure depends upon the fact that the sum of the alphas of the two transistors (α_n is the dc common-base current amplification factor of the PNP transistor; α_p , that of the NPN) can be made to vary with current from something less than unity to something greater than unity.

The high impedance in the forward direction (region I) corresponds to a low alpha sum. If the two alphas were zero, then the PNPN structure would be identical to three noninteracting junctions in series, as shown in Figure 3C, and the leakage current and breakover voltage would be determined by the properties of the center junction. Only slight modifications of this picture are needed if the two alphas are different from zero. So long as their sum is less than unity, the high impedance state persists and the diode is similar to an open-circuit grounded-base transistor.

(This also applies to region IV in the reverse direction, in which case the center junction acts as the emitter for both transistors. Hence the gamma sum, and as a result the alpha sum, can never exceed

FIG. 2. Two basic PNPN structures.



unity. The reverse breakover voltage is the sum of the breakover voltages of the two outer junctions.)

The low impedance state can be understood most easily in terms of the two-transistor model. In the normal active region of a transistor (Ref. 2), the emitter is forward biased, the collector is reverse biased, and the various currents are related as in Equation 1, neglecting saturation currents.

$$I_c = \alpha I_e = \frac{\alpha}{1 - \alpha} I_b \quad (1)$$

If the base current exceeds the value given by Equation 1 (as by restraining the collector current externally and driving the base independently), then the device goes into the saturated state where both emitter and collector junctions are forward biased. Now if two transistors are connected as in Figure 3B and both are driven into saturation, then all junctions will be in a forward bias state. The voltage drop across the center junction then opposes and essentially cancels that of one of the outer junctions, leaving a single forward-biased junction. Thus the two-transistor configuration of Figure 3B presents a low impedance when both are driven to saturation.

The two transistors of the PNPN structure can be driven into saturation without any external base drive because of the "internal" connections. This comes about because the base drive for the PNP transistor is provided by the collector current of the NPN and vice versa. The collector current of the PNP device is $\alpha_n I$. The base current actually supplied, however, is $\alpha_p I$, the collector current of the NPN. Hence the condition of saturation is

$$\alpha_p I = (1 - \alpha_n) I \quad (2)$$

$$\alpha_n + \alpha_p = 1 \quad (3)$$

Similarly, the NPN saturates for the same conditions.

In the PNPN diode, then, the collector junction saturates (goes forward-biased) when $\alpha_p + \alpha_n$ becomes greater than unity and the low impedance state results. On the other hand, the collector is reverse biased and the device presents a high impedance when $\alpha_n + \alpha_p$ is less than one.

To construct a switch with the general V-I characteristic of Figure 1, the device must have the feature that at low currents $\alpha_p + \alpha_n < 1$ and at higher currents $\alpha_p + \alpha_n > 1$. The current at which saturation sets in is the hold current I_h , for which $\alpha_p + \alpha_n = 1$. Several fabrication techniques can make the alphas depend upon current: recombination centers which give rise to low lifetime at low current and high lifetime at moderate currents (Ref. 3, 4, 5, 6); electric fields which increase with current decrease transit time and increase alpha (Ref. 7, 8); a shunt resistance across the emitter base junction (Ref. 1) which can carry most of the current at low levels but only a small fraction of it at higher levels. The various mechanisms all rely specifically on a variation of alpha with current or base charge. Thus the device is properly considered to be current or charge operated rather than voltage operated.

Methods of triggering

The PNP diode may be triggered in several ways. If the voltage across the device is raised above the breakover voltage, current will flow, the alphas will increase, and the device will "turn on" if the external circuit is such to permit the hold current to flow. As soon as the device has switched to the low impedance state, the trigger may be removed and the device will remain "on". Figure 4 illustrates this method of triggering a PNP diode.

Under certain conditions, the diode may also be triggered by a fast rise pulse smaller than the breakover voltage. Since the center junction has capacity, a fast rise pulse causes a current $C_c dV/dt$. If this current is greater than the hold current, the device can reach the low impedance state by "tunneling through" the V-I characteristic. However, a critical amount of charge must be supplied to the base to cause turnon. This charge is supplied by the collector junction, so there is a lower limit to the dynamic breakdown voltage. The charge made available by the collector, $C_c V_o$, must be more than the critical value no matter how fast the rate of rise of the input pulse. The amount of charge required depends upon device design. The dynamic breakdown voltage may be as low as 5 or 10 volts or as high as the static value, depending on design.

FIG. 4. PNP diode triggering circuit. A pulse applied to the capacitor will switch the diode if the pulse voltage plus the bias voltage V exceeds the breakover voltage.

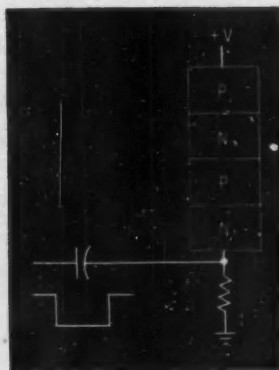


FIG. 5. Static V-I characteristic of three-terminal PNP switch. As the base current I_b is increased, the breakover voltage and the turn-off current decrease. For sufficient values of base current, I_{b0} or greater, the peak of the characteristic disappears completely.



FIG. 6. PNP triode triggering circuit. The simplest method of triggering PNP triodes is to supply base current to the third lead. Coupling may be either dc or ac.

The PNP triode

The PNP structure may also be triggered by supplying base current through a third lead, making a PNP triode (Ref. 9). When base current is supplied, the voltage current characteristic is altered in several respects, the most important being a lowering of the breakover voltage and of the turnoff current. The turnoff current is defined as the minimum collector current for collector saturation when base current is flowing. This decrease comes about because the external base current adds to the internal base currents previously discussed, thus producing saturation at a lower collector current. Although this current is lowered, the device does not become self-sustaining or regenerative until the current across the junction equals the two-terminal hold current.

Figure 5 shows a family of V-I characteristics with various values of the base current as a parameter. Note that the voltage peak can be completely wiped out for sufficiently large values of the base current. This value of base current, called I_{b0} , may be one to two orders of magnitude lower than the hold current. Figure 6 shows a simple triggering circuit for the three-terminal PNP device which is variously called a thyristor, transistor, or controlled rectifier. Again, once triggered, the base current can be removed and the device will remain on for currents greater than I_h .

Methods of turnoff

To turn the device off, the alpha sum must be reduced to a value below unity. This can be accomplished by reducing the current to less than the hold current by open circuiting or by reversing the current flow. Reversing the current is the most rapid.

Under certain conditions PNP triodes can be turned off by withdrawing current through the base

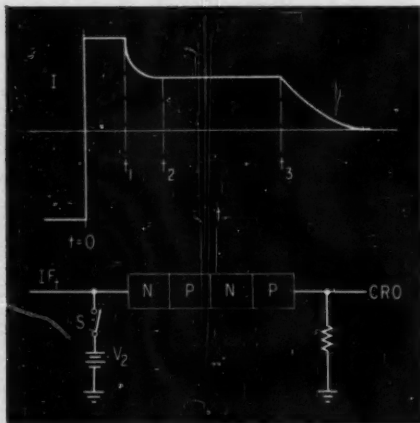


FIG. 7. PNP switch turnoff current waveform. The two storage times (t_0 to t_1 and t_1 to t_2) and decay times (t_2 to t_3 and t_3 on) are shown here.

lead. Most units presently available show little or no gain when turned off in this manner, and some devices cannot be turned off at all through the base when large currents are flowing. In theory, however, large turnoff gains can be achieved in PNPN triodes even when they are carrying large currents, and at least one device possessing this feature has been announced (Ref. 10).

Switching speed

The same factors which determine the speed of other semiconductor devices (i.e., base transit times, junction capacities) apply to the PNPN unit. In addition to the intrinsic transistor parameters, the method of turnon and turnoff is important in determining rise and fall times. The two terminal PNPN structure responds as two grounded-base transistors in series. The limiting factor is the grounded-base response of the slower component transistor.

The triode is normally driven through the base. The transistor with the base connection (NPN in Figure 6) responds as a grounded emitter device. The familiar delay time is followed by a rise time. The collector current for this transistor then drives the base of the PNP in a common collector mode. This implies that the triode, when driven from the base, is relatively slow. But this is applicable only to the initial phases of the transient; for once the sum of the alphas has risen to unity, the base current is relatively unimportant and the device responds as a diode.

Turnoff times are composed of several intervals. There is a storage time, analogous to the storage time in a saturated transistor, which comes about because all junctions are forward biased. A decay time, again similar to that of a transistor or diode, follows the storage interval. Since the PNPN structure is the equivalent of two transistors, two storage and decay times are observed under certain conditions. The factors which determine the storage and decay times are the on and turnoff currents, the base widths, and carrier lifetimes. Narrow-base, low-lifetime units have been fabricated in the laboratory (Ref. 9) which

show recovery times of a few millimicroseconds. Figure 7 shows the current waveform for such a unit.

Power handling ability

The power handling ability of a PNPN diode or triode is significantly greater than that of a three-region transistor of similar geometry and speed and is approximately the same as that of a PN junction diode. This improved power handling ability is due to the ability of the device to handle both high voltages and high current. Three-terminal PNPN units which will switch 10 kw in about 10 microsec are now available commercially.

The basic limitation on the voltage that can be supported when the switch is open is the center junction breakdown voltage. At least one base must be made of high resistivity material to achieve high breakdown voltages. In the PNPN triode this can be accomplished without introducing high series resistance or high base resistance, whereas one or the other is necessarily introduced in a three-region transistor.

The maximum current that the device can carry is high since the conducting PNPN switch is a regenerative device, and the permissible current density is higher because current flow is distributed uniformly over the device area as mentioned before.

The circuit in which a device is used is important in determining the power dissipation. The PNPN device is particularly suited to the high efficiency trigger-type circuit in which little standby power is consumed. Since the device may be frequently switched from the high voltage, low current to the low voltage, high current state, the power dissipated during switching can exceed the power dissipated in either stable state (Ref. 11). This is particularly true in low duty cycle, high repetition rate circuits.

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What's Available in Europe for Electronic Process Control

Concluding the three-article survey of electronic control systems produced in Europe, this part describes six systems from France, Holland, and Germany. The other seven systems were detailed in Parts I and II (June 1960, pp. 103-107 and August 1960, pp. 107-111), together with an introductory discussion of European design trends and a tabulation of salient features for all 13 available electronic control systems.

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ERNEST D. MAY, London, England

As in the United States, control engineers in processing plants in Europe can select both pneumatic and electronic control systems. In particular, electronic systems show a wide diversity of designs and a variety of input and output signal forms and ranges. Because of lack of uniformity amongst available equipment, detailed equipment descriptions are needed as a first step toward control system selection.

Electrofact N. V., Netherlands

Development of the Minireg electronic control system started in 1956, with initial installations two years later in chemical plants in Holland and Germany. The Minireg controller, unlike most others, does not operate directly from the output of the process-variable transmitter. Instead, all measured values are first converted to dc millivolt signals by the transmitter and then fed to an indicating or recording potentiometer. To generate the 0 to 25-vdc input signal required by the controller, 25 volts from a stabilized source in the controller is impressed across a retransmitting slidewire in the instrument.

For temperature measurements from thermocouples, the input to the recorder or indicator is already in millivolts. For pressure, flow, and level measurements, a corresponding mechanical displacement moves the wiper arm of a slide-wire potentiometer in the transmitter to produce the millivolt signal.

The Minireg controller—in conjunction with Electrofact's line of Miniline and Miniscale indicators, recorders, and transmitters—performs at a claimed nominal error of 0.75 percent. Line voltage variations of plus or minus 10 percent produce an additional error of less than 0.5 percent.

As the upper portion of Figure 1 shows, the deviation signal is developed in a bridge system comprised of the measured-value slidewire in the receiver and

of the desired-value slidewire in the controller—both slidewires being energized from the 25-vdc supply in the controller case. A four-tube chopper input amplifier raises the deviation signal to a 0 to 110-volt, 25-ma, 50-cps amplifier output for a two-phase servomotor. Reset and rate functions are developed across RC networks, with a separate buffer amplifier coupled to the reset network to reduce interaction. A slidewire potentiometer at the main amplifier input provides proportional band control.

The controller, Figure 2, features pushbutton selection of control modes. This gives independent choice of P, P-I, P-D, and P-I-D control actions. Proportional band is 2 to 500 percent, rate action is 0 to 2 min. Reset action is calibrated from 2 to 200 min, and by operating one of the pushbuttons, the reset time can be increased to 2,000 min.

Output from the controller can actuate servomotor operated pneumatic relays and switches and electrical contacts and potentiometers. The motor's angular movement actuates small electric or pneumatic switches to provide on-off electric or pneumatic control. However, continuous control can be obtained by coupling the servomotor to a variable transformer or a pneumatic relay. A slidewire on the actuator generates a signal for positional feedback information.

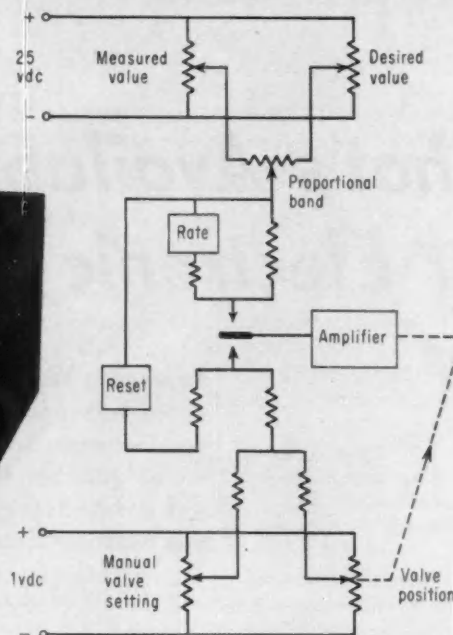
Minireg is contained in a single unit case, with a 182 x 222 mm cutout identical to the Miniline and Miniscale receivers. A duplex case houses both the controller and the recorder or indicator.

Controle Bailey, France

The Transitol system is fully transistorized with transducers for pressure, flow, level, temperature, and mechanical displacement. Conversion of the measured process variable into a physical displacement moves the core of a differential transformer energized

FIG. 1. Simplified schematic of the Minireg controller.

FIG. 2. The Minireg features pushbutton selection of control modes.



from a 4,000-cps transistorized oscillator in the transmitter. The transformer output is rectified by semiconductor diodes and applied as a 1 to 11-vdc measured-value signal to the controller. Measured-value indication at the transmitter is provided through mechanical linkage, with electrical indication also available at the controller. Desired-value setting is derived from a slidewire potentiometer and stabilized dc source in the controller or recorder.

Modular design includes units like blind or indicating P-I controller, indicating ratio controller with P-I action, and a separate rate action package. Common to these is the temperature stabilized printed circuit transistorized amplifier with floating input.

In the controller, adjustable feedback ratio provides proportional band control from 3 to 200 percent, with three plug-in capacitors in the feedback network providing the reset action of 36 sec and 6 and 25 min maximum. Proportional band and reset are adjusted by dials on the controller subpanel, Figure 3. Other plug-in capacitors at the rear of the separate rate-unit amplifier offer derivative time in three useful ranges up to 18 min.

The controller has a 0 to 10-ma dc output range, directly operating an electropneumatic relay with a standard 3 to 15-psi output.

All panel-mounted units are in a standard case size of 75 x 150 mm, with vertically arranged edgewise indicators. Power requirements are supplied by a separate, stabilized, solid state power pack (127 volts, 50 cps input, 24 vdc output) featuring automatic changeover on power failure to a standby battery adequate for 10 min operation. Two powerpack types, 1 or 8-amp outputs, supply either five or 40 units in the control system. Available accessories include ratio adjusters, threshold relays, indicating auto-manual bumpless transfer unit, and selector relays.

The Transistrol system has found particular application in power station boiler control and in nuclear plants.

Controle et Regulation S. A., France

Controle et Regulation makes two electronic control systems, the Magdyne and the Transop.

► The Magdyne systems uses force balance transmitters and magnetic amplifiers. In the force balance transmitters for pressure measurement or sensing any mechanical displacement, deflection of a beam by the input is detected by displacement of a differential transformer's core. The signal thus developed is fed

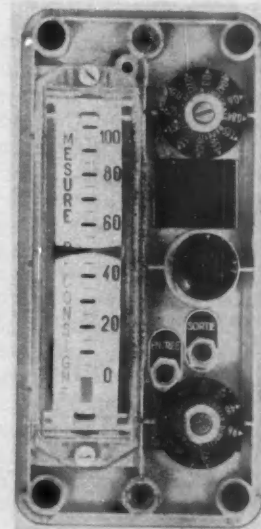


FIG. 3. The Transistrol is tuned to the process using adjustments located on the controller's subpanel.

to a magnetic amplifier. Varying the input displacement point-of-contact along the beam gives an 8 to 1 scale range adjustment. Beam balance is achieved by feeding back the magnetic amplifier output current to a coil in the field of a permanent magnet. The feedback current forms the 0 to 10-ma dc transmitter output going to the controller via two wires of the four-wire transmission system. The other two wires carry 127 or 220 volts, 50 cps to power the transmitter amplifier.

Transmitters with an accuracy of 1 percent and a response time of 0.5 sec are available in watertight or explosion-proof versions. Transmitter variations include those capable of performing multiplication, division, addition, and subtraction of process-variable measured signals.

Error sensing between measured and desired value signals occurs in a separate self-balancing potentiometric recorder using magnetic servoamplifiers. The error signal is generated from a resistance bridge, one arm being the desired value and the other a slide-wire potentiometer ganged to the measured-value servopot in the recorder. The recorder provides for manual control and bumpless auto-manual transfer.

The Magdyne controller contains two magnetic amplifiers fed from the recorder. In the first amplifier stage, controls in the feedback circuit give a proportional band of 2 to 200 percent and rate action of 0.2 to 10 min. Reset action, 0.01 to 10 min, is accomplished in the feedback circuit of the second amplifier. Controller output is 0 to 10 ma dc into 2,500 ohms. This electrical signal drives a force-balance electropneumatic converter incorporating a pneumatic relay to operate conventional pneumatic actuators and positioners. Claimed conversion accuracy is 0.5 percent. Electrohydraulic valve actuators can also be used in the Magdyne system.

► The Transop control system employs differential transformer transmitters and vacuum tubes in controllers and receivers. For process variables which result in a displacement of the transformer core, the transmitter output is 0 to 500 mv ac. To get this same signal for temperature measurements using a resistance temperature detector, a resistance bridge develops the signal without additional amplification.

As in the Magdyne system, a separate potentiometric recorder generates the error signal going to the three-term controller. A printed circuit amplifier,

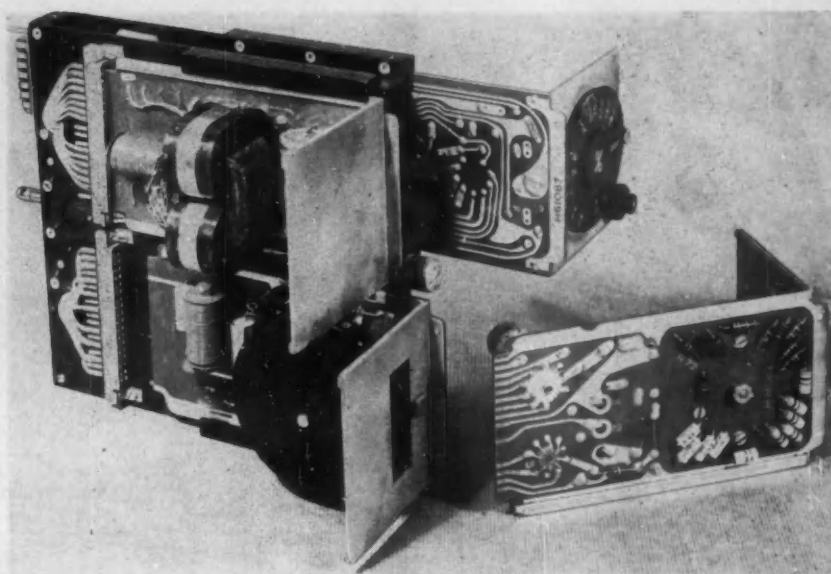


FIG. 4. Controle et Regulation's Transop controller.

Figure 4, is used for each term in the controller. Varying the feedback ratio in a high gain, two-tube amplifier—the first stage—yields a proportional band of 2 to 200 percent. The proportional ac signal is then converted to dc and fed to two dc amplifiers in series. In the first dc amplifier an RC network in the feedback loop provides a rate action of 0.01 to 30 min. Reset action is from another RC network, this time in the second dc amplifier, and covers a range of 0.01 to 30 min. Controller output is 0 to 5 ma dc into 12,000 ohms.

J. C. Eckardt GmbH, Germany

The Eckardt three-term controller—still in its development trials—has a 0 to 10-ma dc signal level common to both input and output. Operating with the Eckardt line of mechanical transducers for pressure, differential pressure, flow, and level measurements, add-on units convert mechanical deflection to the 0 to 10-ma dc measured-value signal. This signal is carried to the controller by way of a four-wire transmission arrangement.

For flow and pressure measurements the error signal is raised by a magnetic amplifier to plus or minus 10 vdc. For temperature measurements the ac unbalance signal from a resistance thermometer bridge circuit is increased by a one-tube amplifier and then rectified to give the same plus or minus 10-vdc signal. For either arrangement the dc signal feeds the reset and rate RC networks and amplifiers to give three-term control.

Three separate chassis make up the controller, Figure 5, within a single 192 x 288 mm case. The upper section contains the proportional amplifier with proportional band adjustment; the middle section, the time function generators; and the lower

FIG. 5.
The Eckardt controller
incorporates three
chasses in one case.

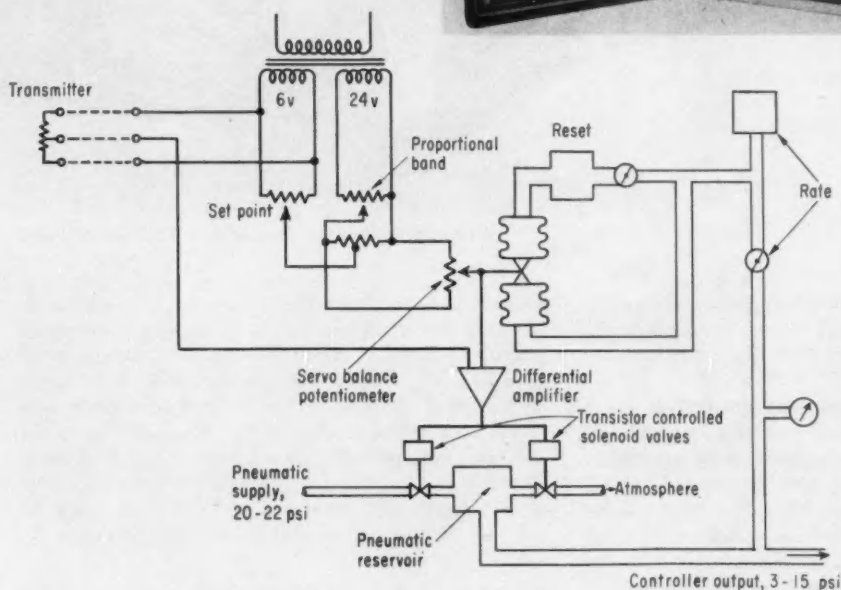
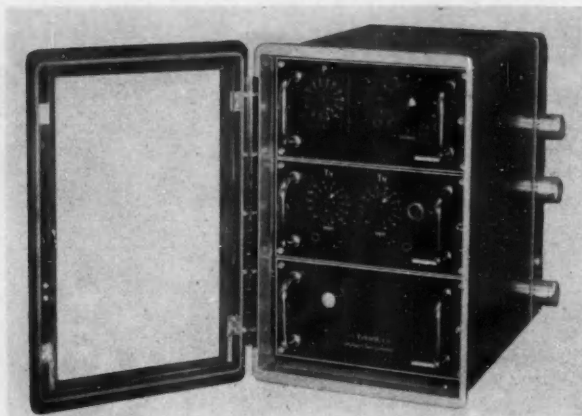


FIG. 6.
The Arca-Broida controller
combines electronic and
pneumatic techniques to
obtain three-term control

section, the stabilized power supply.

A 13-step adjustment provides proportional band control of 1 to 240 percent. Other 13-position switches give reset times of 0.2 to 40 min and rate times of 0.1 to 10 min. Interaction between terms is claimed to be negligible because of parallel connection of the RC networks.

Additional features of the Eckardt system are an amplifier input configuration allowing for ratio control, external resetting, and cascading and built-in test points and bumpless transfer facilities. Eckardt supplies pneumatic diaphragm actuators and positioners, and under development is an all-electric actuator.

*Societe Francaise des Regulateurs
Universels Arca, France*

The Arca-Broida control system, Figure 6, features electrical proportional control and pneumatic reset and rate terms, the advantage claimed for this design being low cost and constructional simplicity. The difference between the measured and desired values is

fed to one input of a single-tube differential amplifier. The other input to the amplifier is from the wiper arm of a pneumatically driven servopotentiometer across which is developed a voltage depending on the proportional band setting.

Following a disturbance the resulting error signal at the differential amplifier operates one or the other of the thyatron controlled solenoids in the pneumatic line, effecting a disturbance-correcting change in the controller's output. The 3 to 15-psi controller output also feeds the pneumatic servo bellows via reset and rate capacities and restrictions to move the wiper arm so as to bring the net input to the amplifier back to zero.

Proportional band is 0 to 100 percent, rate action is 0 to 1 min, and reset action is 0 to 30 min. Meters on the controller panel indicate electrically the unbalance between measured and desired values and pneumatically, the valve position, controller output pressure. Neon indicators in the thyatron circuits show deviation-signal direction.

Mechanizing the Adaptive Principle

GIST: Author Gibson describes seven typical controls that have been called adaptive, ranging from one that is commercially available to one that is just an idea. The seven:

- Quarie controller
- Opcon
- Minneapolis-Honeywell's bang-bang system
- MIT system
- Sperry flight control system
- Aeronutronic adaptive system
- Kalman's approach

This is the second article in an important three-part series describing the adaptive principle. In the first article, "Making Sense out of the Adaptive Principle", August '60, pp. 113-119, author Gibson defined adaptive controls and discussed the three criteria required by the definition. In the next article he will discuss further applications of adaptive control and its future.

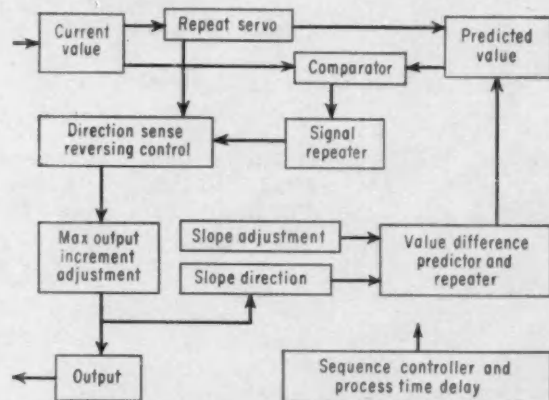


FIG. 1. The Quarie controller, a digital control.

J. E. GIBSON, Purdue University

Several attempts have been made to classify adaptive systems according to one rule or another (Refs. 1 and 2), but in each attempt the class distinctions invariably turned out to be arbitrary with many obvious similarities between classes (Ref. 3). At present there seems to be no technique for classifying that is applicable to all cases all the time. The adaptive principle has been applied in a number of interesting ways in both industrial and military applications. Here are descriptions of seven systems which have been called adaptive.

The Quarie controller

One of the first adaptive controls to become commercially available was the Quarie controller, a digital controller in action since it acts in a step-wise manner rather than a continuous fashion. Now marketed by Fisher and Porter Co., the device per-

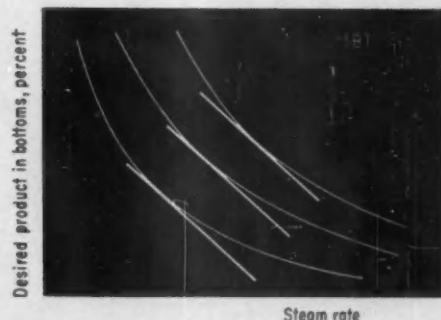
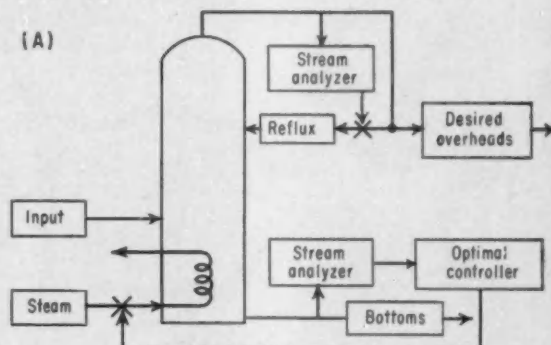


FIG. 2. A—Quarie controller applied to a process. B—Selected slope of steam rate depends on value of reclaimed product and cost of additional steam.

forms its logic with mechanical cams and mercury-wetted relays. The Quarie controller (Figure 1) optimizes a physical quantity that can be measured by a transducer, rather than maximizing or minimizing some theoretical figure of merit. It operates by disturbing the setpoint or input to the system and observing the effect of this disturbance.

Since the controller calculates the slope of the variable which is being optimized and compares this to the desired slope, the controller can be set to seek some finite slope rather than a peak or zero slope. The size of the incremental step—determined by the amount that the calculated value of slope at the present setpoint differs from the desired slope of setpoint—decreases as the controller approaches the optimum setting and the difference between the actual slope and the desired slope becomes small. This decreases the hunting loss and overshoot.

Here is how the Quarie controller might operate in a typical application, one where the desirable point of operation is not at zero slope (Figure 2A). The process is a fractionating column in which the overhead product is being held to a constant purity by a stream analyzer controlling the reflux rate. The bottoms will also contain some percentage of the desired product, the amount depending upon the amount of steam used. Since the mixture in the input lines is not constant, a family of curves represents the percent desired product in the bottoms vs lb of steam per lb of input. The desired point of operation on Figure 2B is the slope at which the cost of the required steam to reclaim is equal to the cost of the overhead product lost in the bottoms.

Using stream analyzer information, the Quarie controller can control the steam to this point in spite of variations in the input mixture. The operator has only to set the desired slope, the size of initial step increment, and the length of time between steps. The sequence of operations:

- 1) The steam rate is changed by an incremental

value. The controller multiplies the initial increment by the desired slope to establish a test value of the dependent variable, in this case percent desired product in bottoms.

- 2) The Quarie controller, after waiting the desired time increment to allow the transient to die out, accepts from the stream analyzer the actual value of the percent product.

- 3) The actual value is subtracted from the test value. The sign of this result determines whether the incremental steps should be continued in the same direction or reversed; the magnitude determines the size of the increment.

- 4) At each step a new test value is computed since this depends on the size of the step increment. The size of the increment reduces to zero, thus preventing overshoot and continued hunting.

If the curve of the variable to be controlled was such that the same valued slope might appear twice—once near the minimum and once near the maximum—the designer can set the controller to seek the one correct slope desired. With such a constraint imposed, the controller cannot become bistable, oscillating between the two values of proper slope.

The Opcon Controller

In basic theory of operation, Opcon, built by the Westinghouse Electric Corp., appears quite like the Quarie controller, but the implementation is different. Other differences:

- a) Opcon is a multivariable controller (Figure 3). It can control two or more input variables to set the optimum value of the output. Thus, rather than searching along a line for an optimum, Opcon searches in two dimensions or in an area.

- b) Incremental step size is constant until an optimum is reached, then the step size is reduced.

- c) After the optimum is found, small incremental steps are still periodically made so that, if the optimum drifts, the inputs will be adjusted to search out the new value of the optimum.

- d) The Opcon controller is a much larger and complex device. Logic is performed by solid state devices and transistorized circuitry.

Opcon has been used in a production line in a Westinghouse plant for capacitor checking by balancing the arms of a bridge circuit automatically. It has also directed a dehydrogenation pilot plant operation at Dow Chemical (CtE, Nov. '59, p. 124), and Sun Oil has installed it in a catalytic cracking tower control.

Although Opcon has the capacity to optimize to a complex figure of merit, present applications have been limited to simpler criteria that are usually directly measurable physical quantities. This has simplified

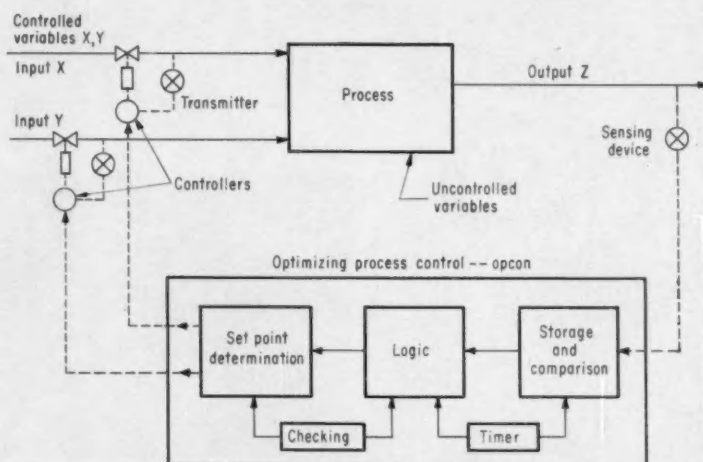


FIG. 3. Opcon applied to control two variables in a process.

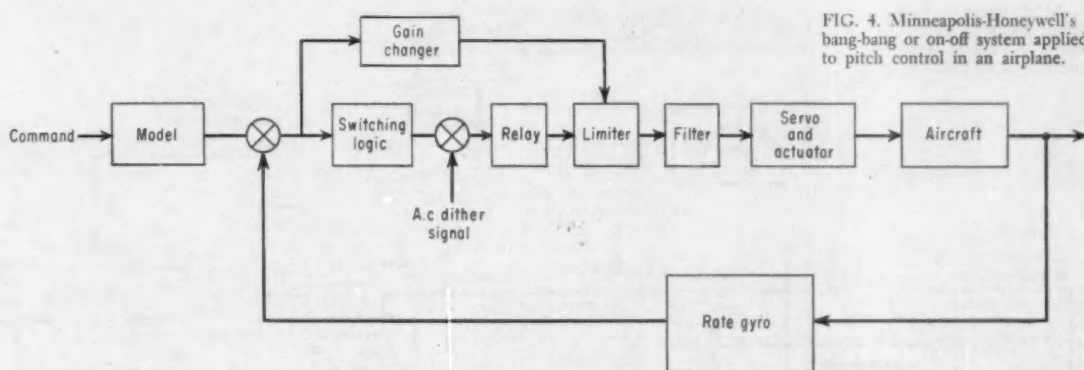


FIG. 4. Minneapolis-Honeywell's bang-bang or on-off system applied to pitch control in an airplane.

it and precluded the need for a large-scale computer.

All of its applications up to the present have been in two-variable control, but Opcon has been designed for multivariable control. It is not easy to adjust two or more parameters automatically so that an optimum is reached quickly—and followed should it move. This is called the strategy of search and requires efficient procedure; it cannot be done in a random manner. Such procedures are called methods of steep descent and will be discussed in the next article.

Minneapolis-Honeywell's Bang-Bang system

One of the earliest systems, called adaptive, applied to aircraft control was the so-called "bang-bang" or on-off control. It is based on the work of I. Flugge-Lotz and C. F. Taylor (Ref. 5) who devised a system to maintain minimum dynamic error between arbitrary inputs and the output of a linear system with unspecified parameter values. The Flugge-Lotz-Taylor system relied on a discontinuous feedback.

Minneapolis-Honeywell (Ref. 6) has built a bang-bang system which has been flight tested in a F-94C aircraft (Figure 4). Basically M-H developed a method to change the gain of the control. It has inserted a nonlinear element—a relay—into the control system. Relay characteristics, however, are modified by an ac sinusoidal dither signal so that the apparent relay characteristic is a function of the wave form used. Behind the relay in the control system is a limiter which permits attenuation of the relay output when the gain changer is operative.

The gain changer, a lag network, attenuates limiter output when the pitch rate error (Figure 4) is below a prescribed threshold. Any time the error is above the prescribed threshold, full relay output is available. Pitch rate error thus becomes the key variable in this system.

One concern with a relay system is the possibility of setting up large amplitude limit cycles or oscillations in the control system. By the proper selection of components such as filters and gyros, limit cycles were minimized. In flight tests none developed.

This approach produces an extremely tight inner loop control, so much so, that if abrupt commands

were imposed on the system, the airframe response would be too harsh for the pilot. To prevent such response, inputs are shaped with an analog model.

The M-H bang-bang adaptive system can operate only over a limited range of parameter variations. The company is now studying several techniques to widen the range of parameters.

The MIT System

The Instrumentation Laboratory at MIT has designed an aircraft adaptive control system that puts a model to different use. In the MIT system (Figure 5), the model is designed to have a response compatible with the performance characteristics of the aircraft, and a change in the model is exactly equivalent to a change in the system's specification. Then the difference between the model response and the aircraft response changes the system parameters. The design objective of the adaptive portion is to minimize this response error under all operational conditions of the system. To do this, system loop sensitivities and compensation parameters are adjusted to null or minimize selected junctions of the response error signal.

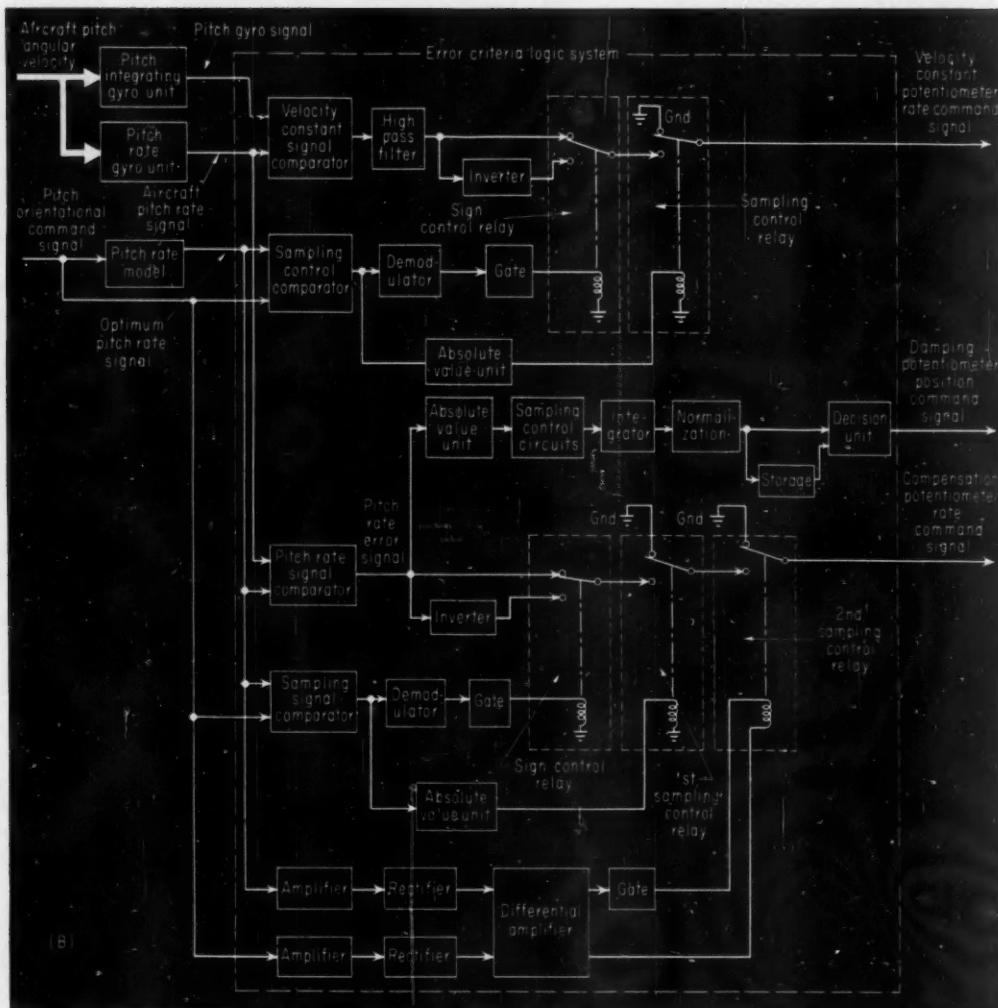
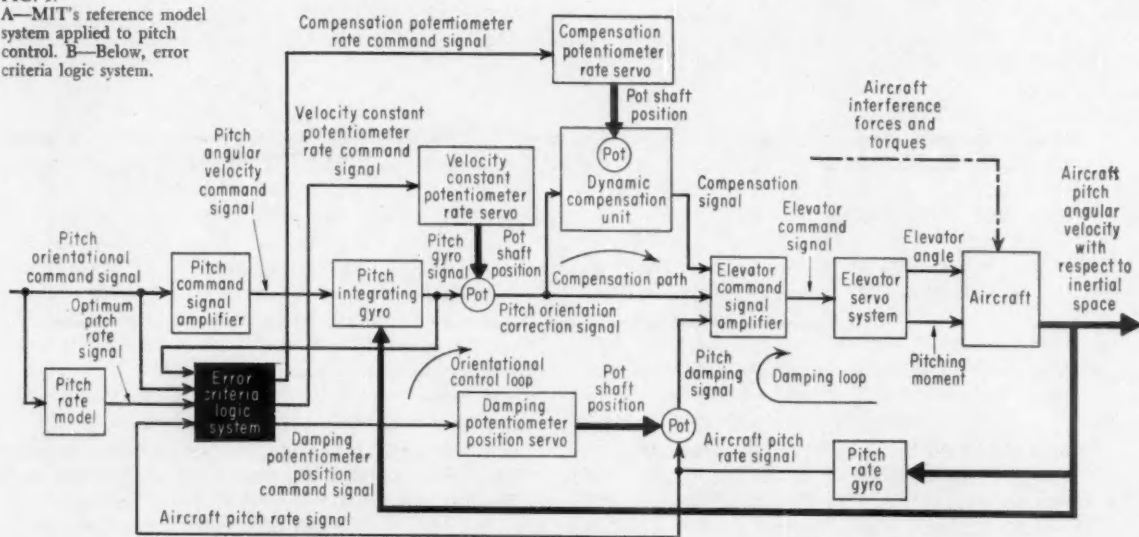
All the information required to adjust the parameters is obtained from the input signals that result during normal operation of the system. No test inputs are used. The adaptive process includes sampling the error and generating the error functions to evaluate system performance. In general, the error criteria are defined as functions of the error quantity examined over some defined sampling time.

How this approach might be applied to control the pitch of an aircraft is illustrated in Figure 5A. The key is the error criteria logic system (black block) which contains the sampling control circuitry and which generates the potentiometer control signals—the mode of adaption. This error criteria logic block is a complex system in itself (Figure 5B). The outputs of the logic system position three sensitivity control servos, the number necessary to satisfy the error criteria of the system.

The MIT design technique for adaption makes adjustments to a control system whose feedback con-

FIG. 5.

A—MIT's reference model system applied to pitch control. B—Below, error criteria logic system.



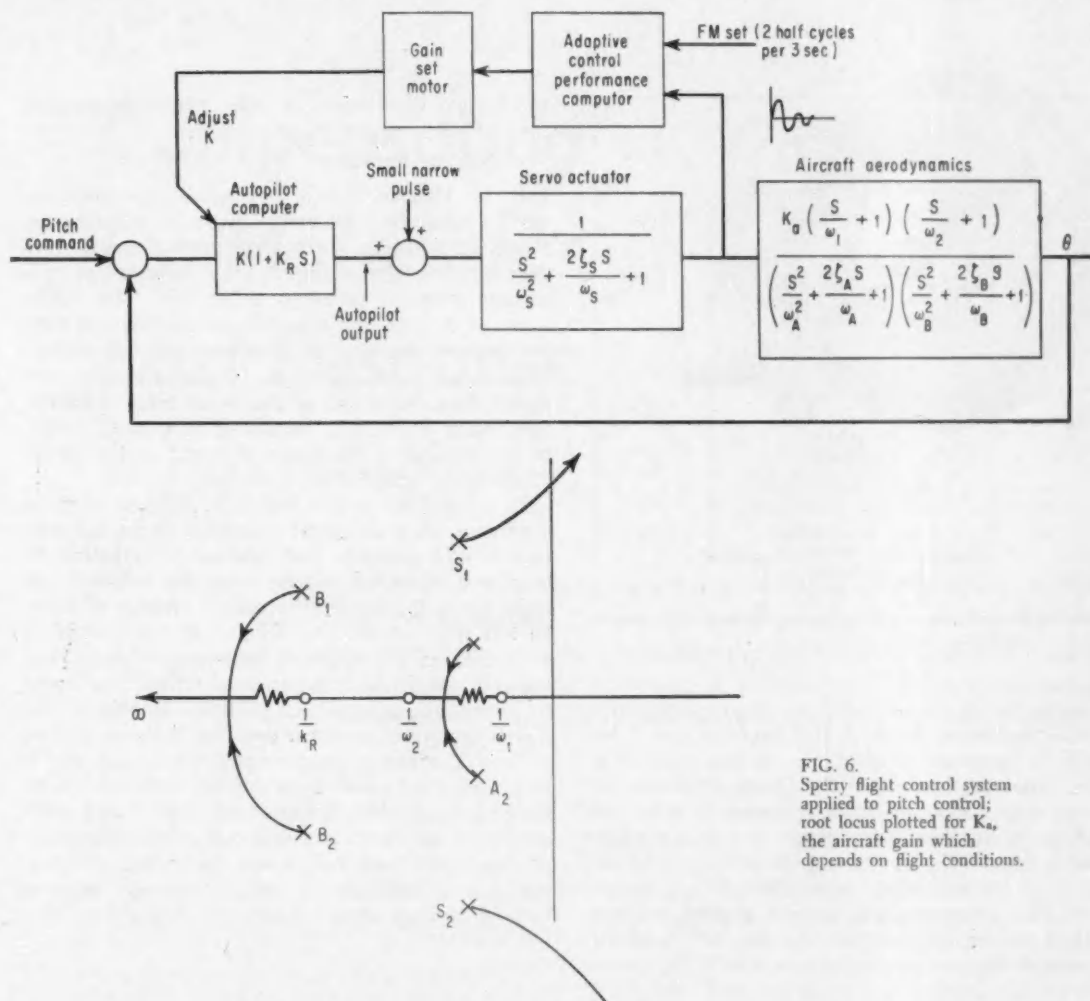


FIG. 6.
Sperry flight control system
applied to pitch control;
root locus plotted for K_a ,
the aircraft gain which
depends on flight conditions.

control loops are closed independently of the adaptive loops. If the adaption part of the system should fail, the control remains as a closed-loop system.

The Sperry flight control system

The Sperry Gyroscope Co. has proposed an adaptive flight control in which it is assumed that the form of the plant is known in advance. The Sperry system attempts to measure the exact location of a pair of high frequency poles that are known to exist and to give trouble by moving as a function of flight conditions, then to control the location of these troublesome poles by gain adjustment. The Sperry system is a special purpose, single dimensional adaptive control. As shown in Figure 6, the high frequency servoactuator poles can cause closed-loop instability as K_a (aircraft gain) increases due to aerodynamic conditions. It is proposed to adjust K , the gain of the autopilot computer, to bring these high frequency poles into a more satisfactory position.

Since the open-loop poles of the servoactuator are the cause of the instability, the Sperry approach is to excite the actuator with a low amplitude, narrow

pulse, then to observe the output transient of this device. The transient will be of the form of a decaying oscillation. The adaptive loop counts the number of half cycles of this oscillation; this number is a measure of the damping ratio of the system. By a study of the system performance, it was decided that two half cycles in the measuring period of 3 sec yielded the proper damping factor. A count less than this will cause the gain adjustment motor to increase K , while a count greater than two will cause a decrease in K . Provision is made to adjust the rate at which pulsing occurs as a function of the rapidity of variation of parameters.

The Sperry system represents a solution to a special problem. By applying all of his knowledge of the plant to the adaptive loop design, the engineer can simplify the design, tailoring it for the particular application. The system could not be used with a different plant than the one for which it was designed.

The Aeronutronic adaptive system

The Aeronutronic Div. of Ford Motor Co. (Ref. 9) has proposed a complete adaptive control that

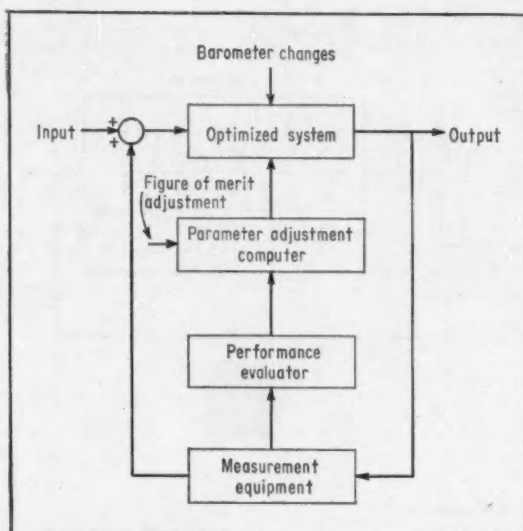


FIG. 7. Aeronutronic adaptive system.

measures the figure of merit and then manipulates system parameters to drive the figure of merit towards its optimum (Figure 7). In this sense it is more advanced than either the Quarie controller or Opcon since neither of these optimize to a derived figure of merit. The Aeronutronic system is a single variable control in its present form but could, in principle, be extended to multivariable control. Among its interesting and unique features are the method of perturbation and the manner in which the weighting function is obtained and the figure of merit calculated.

Perturbation is accomplished by random binary noise which is added to the normal input. Cross-correlation techniques are employed to determine the weighting function of the system and from that, the figure of merit. Because of the use of random, discrete interval, binary noise—noise can assume only the levels of plus or minus 1 and that can change levels at only certain points in time—the multiplication that must take place in the cross-correlation between this noise and the output is reduced to a simple gating operation. A further simplification may be effected by substituting a tape recording of a proper sample of the output of an actual binary noise generator. At the same time the recorded noise sample permits the use of spaced magnetic tape pickups to obtain the various values of delay time required by the cross-correlator. Some 12 values of delay are used to calculate 12 points on the weighting function of the system as an approximation of the complete weighting function, simplifying the analysis.

While this partially analog approach is not simple, it is more practical than attempting to incorporate a large scale general purpose digital computer in the loop to accomplish the calculations. And the use of cross-correlation techniques does not depend upon

pre-design knowledge of the plant parameters.

The Kalman approach

R. E. Kalman, RIAS, has been responsible for certain interesting theoretical work on adaptive systems. In addition, he has designed a special purpose combination analog-digital computer for optimizing chemical processes (Ref. 10). The device operates by sampling the error periodically and then determining the control coefficients by correlation techniques. The operation of the adaptive controller depends on normal inputs and noise to disturb the system rather than employing an external means of perturbation. The figure of merit is the rather crude mean square error criterion.

In some later work (Ref. 11), Kalman suggests a general purpose digital computer as an adaptive control and proposes that external perturbation be employed when the process nears the setpoint and noise tends to obscure the correct sensing of error. In this work he proposes a figure of merit which is an integral of the square of time-weighted error, but the time weighting is exponential rather than linear or square law, as have been proposed by others. The digital computer program employs the concepts of Bellman's dynamic programming (Ref. 12) which is a somewhat novel approach to the problem of steep descent. While the mathematics and philosophy of adaptive controls is in a rudimentary state at present, Kalman's approach through topological methods and the concept of state variable appears to hold some promise.

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Compensating Dc Motors for Fast Response

S. W. HARRIS, General Electric Co.



FIG. 1. View of frame of compensated motor shows coils inserted before varnishing.

Inductance rather than inertia is sometimes the greater obstacle to fast acceleration of dc motors. Compensated motors solve the inductance problem and, in addition, are more adaptable to field forcing and severe duty cycles than conventional dc machines. A simple check involving damping factor helps control engineers decide when to specify compensated motors.

When selecting a dc motor for use in a closed-loop system, the control engineer often considers only the inertial or mechanical time constant of the motor. He bases his calculations for stability, allowable amplification, accuracy, and speed of response on its value alone. But in so doing the control engineer is neglecting a second vital factor, the inductive time constant, which at times actually imposes far greater limitations on system performance than does the mechanical time constant. This oversight is especially unfortunate because excessive inductive time constants are easily reduced by a simple expedient: the use of compensated motors.

Analytical studies of the transfer function of dc motors have shown that the over-all time constant T must be optimized when fast acceleration or response is required. The time constant is as follows:

$$T = \sqrt{T_M T_L}$$

where T_M = mechanical time constant, defined as the time in seconds to accelerate the motor and load inertia to 63.2 percent of its final speed when a dc voltage of constant magnitude is suddenly applied to the motor terminals.

T_L = inductive time constant of the motor circuit or the familiar L/R .

The mechanical time constant is found from the following equation:

$$T_M = \frac{RJ}{K_T K_V}$$

where R = total motor armature circuit resistance, ohms
 J = total motor and load inertia referred to motor shaft, slug-ft-sec²

K_T = torque constant of motor, lb-ft per amp

K_V = voltage constant of motor, volts per rad per sec

While performance analysis should always properly

begin with examination of the over-all time constant, the control engineer will find that under certain circumstances either T_M or T_L will be the dominating factor. In this case, the analysis can proceed on the basis of this constant alone and the second factor can be safely ignored. The criterion for determining whether or not a single constant dominates is the damping factor ζ , or:

$$\zeta = \frac{T_M}{2\sqrt{T_M T_L}} = \frac{1}{2}\sqrt{\frac{T_M}{T_L}}$$

When ζ is greater than 1 (i.e., when T_M is greater than T_L) the motor performance is generally dominated by the mechanical time constant. When T_M is considerably more than T_L , the effect of T_L can be neglected and motor selection made purely on the basis of the mechanical time constant. Under these conditions, conventional or modified shunt wound, separately excited motors give the desired performance, provided large peak torques and high linear torque per ampere are not required.

When ζ is less than 1, which indicates that T_L and T_M are of the same order of magnitude, the over-all motor time constant $\sqrt{T_M T_L}$ prevails. Optimum response is obtained when the damping ratio ζ has a value greater than 0.6 but less than 1.0. As T_L becomes equal to T_M , the response tends toward instability. And a damping ratio lower than 0.4 produces a definite oscillatory response that might be quite objectionable. Thus, when ζ is less than 0.6, T_L is the dominating factor and the control engineer must seek some means to reduce it. The simplest solution to this problem is often the choice of a

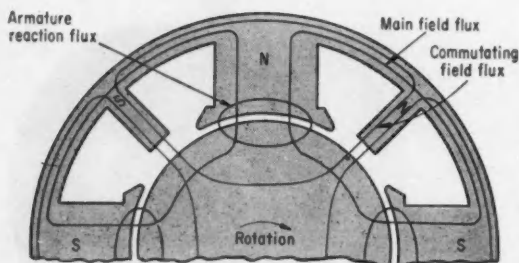


FIG. 2. Paths of armature reaction and commutating field fluxes.

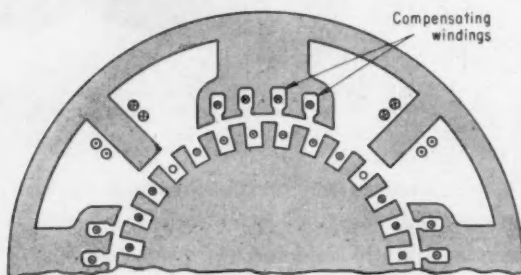


FIG. 3. Cross section of dc motor shows location of compensating winding.

compensated dc motor—for the following reasons.

Armature circuit inductance

The inductance of a dc motor circuit is primarily a function of the geometry of the windings, the number of turns, and the permeability of the iron structure. Its major components are as follows:

1. Inductance due to flux crossing the main pole gap.
2. Inductance due to flux across the armature slots.
3. Inductance due to flux across the interpole or commutating pole gap.
4. Inductance due to leakage flux linking the commutating pole coil and the armature conductors.

Figure 2 shows the location of the first three fluxes in a typical shunt machine. The fourth flux exists mainly in the interpolar space and on the ends of the armature and pole punchings.

Motor designers can reduce armature circuit inductance by using compensating windings, by decreasing pole arc, by increasing or grading the air gap, and by other means that lessen or eliminate flux linkages. In general, all standard industrial shunt wound motors feature some grading of the air gap to lower inductance and armature reaction. However, a further increase in air gap grading requires a proportional increase in field power that can cause the machine to overheat. The same is true when pole arc is decreased. The most practical way by far to cut armature circuit inductance appreciably is the use of distributed compensating or pole face windings. Depending on other machine parameters, the value of inductance may be cut to from one-third to one-sixth that of comparable shunt machines. And

in specially designed machines, even greater reductions are feasible.

Figure 3 shows the arrangement of the compensating winding in the pole face slots. The winding is in series with the armature and commutating poles and carries the same current. However the design is such that the direction of current flow is opposite to that of the armature. Figure 4 illustrates the interaction of the magnetomotive forces set up by each of the armature circuit windings. Because the number of compensating winding turns is equal to the number of equivalent armature turns under the main pole, they effectively cancel the mmf of the armature conductors.

The effects of the compensating winding are:

1. The component of armature inductance due to flux circulating through the main pole air gap is substantially eliminated.
2. The number of turns on the commutating pole can be reduced by an amount equal to the number of compensating winding turns, because the latter set up mmf's aiding the commutating poles. Hence, the component of inductance associated with commutating pole leakage flux is reduced. The reduction is considerable, being proportional to the square of the number of turns on the commutating coil.
3. The end winding component of inductance is substantially lowered because the end connections of the compensating winding usually project over the end windings and their ampere turns are opposed.
4. One disadvantage is the addition of a component of inductance due to flux crossing the slots that carry the compensating winding, Figure 5. This component is identical to the armature slot leakage flux, and its value is roughly equal to γ times armature slot leakage inductance, where γ is the ratio of pole arc to pole pitch. The armature slot leakage flux component of inductance is generally small, usually below 10 percent of the total inductance. Therefore, the additional inductance does not appreciably diminish the over-all improvement.

The net result of adding compensating windings,

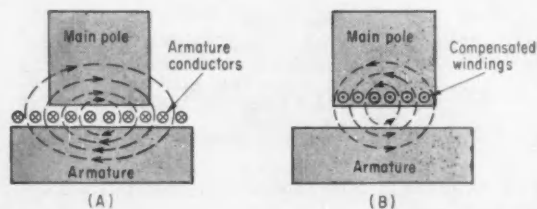
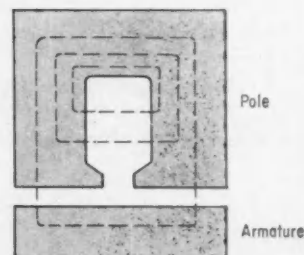


FIG. 4. Fluxes set up by current in armature and compensating windings.

FIG. 5. Leakage flux across pole face slot, which contributes to motor inductance.



Comparison of Typical Compensated and Conventional Motors

Rating	Conventional Shunt				Compensated				Ratio Shunt/Compensated	
	T_L	T_M	$\sqrt{T_L T_M}$	ζ	T_L'	T_M'	$\sqrt{T_L' T_M'}$	ζ'	T_L/T_L'	$\sqrt{T_L T_M} / \sqrt{T_L' T_M'}$
7½ hp, 1,750 rpm	0.0167	0.0423	0.0265	0.796	0.00398	0.047	0.0137	1.72	4.2	1.93
10 hp, 1,750 rpm	0.0187	0.0341	0.0252	0.676	0.00474	0.0358	0.013	1.37	3.95	1.94
20 hp, 1,750 rpm	0.0287	0.0231	0.0258	0.45	0.00661	0.0246	0.0128	0.965	4.34	2.02
60 hp, 1,750 rpm	0.0498	0.00896	0.0211	0.212	0.00982	0.0103	0.00961	0.535	5.06	2.19
125 hp, 1,750 rpm	0.1	0.0121	0.0348	0.174	0.0292	0.0149	0.0209	0.357	3.43	1.66
150 hp, 1,750 rpm	0.115	0.0155	0.0421	0.184	0.0336	0.0172	0.024	0.359	3.43	1.75

T_L includes resistance and inductance of motor armature circuit only.

T_M includes inertia and resistance of motor only.

then, is a significant reduction in inductance. At the same time, the armature circuit resistance is raised. While this increase causes a further reduction of the inductive time constant, it makes the mechanical time constant greater at the same time. The reduction in inductance, however, has the greater effect. The inductive time constant is reduced generally to from one-third to one-sixth of its original value, whereas the mechanical time constant is increased by only 5 to 30 percent. Thus, the over-all motor time constant, which is proportional to the square root of the product of T_L times T_M , is smaller.

The accompanying table lists representative time constants and damping factors for some typical compensated motors alongside comparable characteristics for the same motor without the compensating winding. (Note: Conventional shunt motors with large graded air gaps will have better than indicated values of T_L , $\sqrt{T_L T_M}$ and ζ . Comparison in this manner is made to point out directly the manner in which compensating windings reduce these terms.) The values for the motor inductive time constant T_L includes only the motor resistance and inductance because a zero impedance source is assumed. Also, the mechanical time constant T_M is based on only the inertia of the motor. However the power supply impedance and load inertia must be included to obtain the final motor time constants. If the power supply impedance and load inertia exactly match the motor impedance and inertia, then the values shown in the table are the actual motor time constants. Generally, optimum over-all performance is obtained by matching the power supply and load in this manner.

It is seen that the inductive time constant becomes larger as the motor size increases. Conversely, the mechanical time constant tends to decrease. This makes the use of compensating windings more desirable as the frame size increases. With very large dc machines, the use of pole face windings becomes mandatory for the most practical designs.

Effects of compensation on performance

In the normal shunt machine, armature current sets up cross or transverse magnetization that distorts the main field, Figure 6. If armature current

is high, the cross mmf may actually exceed the main field mmf at one pole tip and thus cause a reversal of flux there. Because of saturation, the flux at the opposite tip cannot increase by a corresponding amount so that a net reduction of main field excitation results. This weakened field leads to a loss of torque which is proportional to flux. In addition, the distorted field excitation causes excessive peak commutator bar-to-bar voltages under the pole tip having the higher flux density. This condition is accompanied by destructive sparking or flashover at the brushes under high loads.

Because torque depends on both current and flux, distortion or reduction of main field excitation places a definite limitation on the torque available from an ordinary shunt motor. Therefore, initial calculations of maximum acceleration rate may be in error if the motor is to be operated beyond the point where essentially constant flux exists. Similarly, a reduction in flux with overloads causes a drop in counter emf and an increase in speed. If the overload is high enough, it is possible for runaway to occur.

Compensating windings overcome these drawbacks to optimum motor performance. Clearly, if the transverse mmf of the armature (armature reaction) is balanced by an equal and opposite mmf having the same distribution in space, the distortion of the field is completely eliminated. This, in fact, was the original purpose of the compensating windings. And counteracting armature reaction by the use of these windings means a more linear torque vs current characteristic as well as higher peak torques, Figure 7.

The higher peak torque capability is probably the most important advantage of the compensated motor. It allows forcing of the machine under transient conditions, resulting in faster response. The 10-hp design in the table, for example, has rated torque of 30 ft-lb and a torque constant of 0.307 ft-lbs per amp. The peak torque of the shunt motor is 107 ft-lb, while that of the compensated motor is 256 ft-lb. These higher torques make it possible for the compensated motor to come up to speed 2.3 times as fast as the shunt motor. This capability underlies the "forcing" technique often used by system designers. By selection of a large enough power supply, the motor response can be forced to be much less

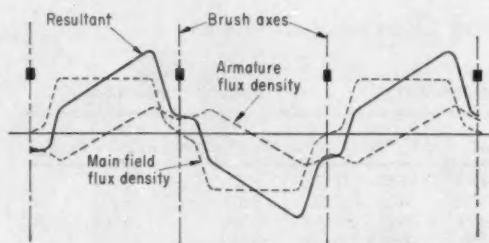


FIG. 6. Distorted flux pattern resulting from interaction of main field and armature reaction mmf's.

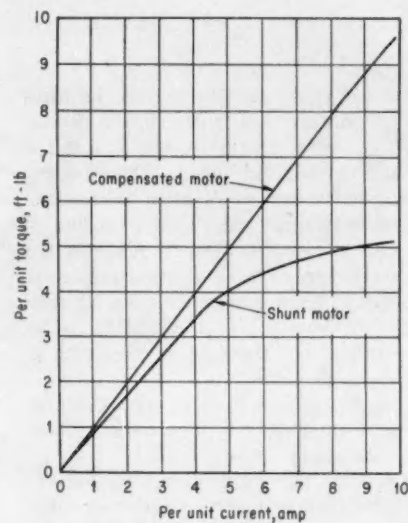


FIG. 7. Torque-current characteristics of separately excited shunt motor compared with that of compensated motor

than its usual mechanical time constant. The compensated motor allows more than twice the forcing of a shunt motor. In the case of duty cycles with high short time peaks but low rms values, the designer can specify a smaller motor if he goes to the compensated type. The smaller motor, of course, offers the benefit of lower inertia and smaller effective time constants.

Some companion advantages of the compensated motor are:

1. Minimized flashover.
2. Improved commutation because of more uniform bar-to-bar commutator voltages with reduced peaks.
3. Longer brush life.
4. Permits operation with high fluxes, a necessary condition for optimum motor design.
5. Permits smaller air gaps, which require less main field power. Lower main field dissipation can result in a small improvement in efficiency, although the primary benefit is from the standpoint of motor heating and, thus, service life.
6. Allows use of concentric air gaps, which also reduce main field power and yield a more uniform

bar-to-bar voltage. In contrast, most standard shunt motors employ graded air gaps to increase the reluctance of the air gap at the pole tips and thereby minimize the effects of armature reaction. But grading increases effective gap length and requires more mmf for a given flux. Grading also causes high flux densities in the armature teeth under the center of the pole, which also call for an increase in the main pole mmf.

Availability of compensated motors

Most manufacturers of dc motors offer a wide range of compensated motors from fractional hp up through the largest integral hp sizes. In the past, most of these machines were custom designed for particular applications. The use of compensated motors was accelerated during World War II to provide the high degree of accuracy, rapid acceleration and fast response required for gun fire control, radar antennas, and other servo drives. This led to the development of complete lines of compensated motors, particularly in ratings below 100 hp.

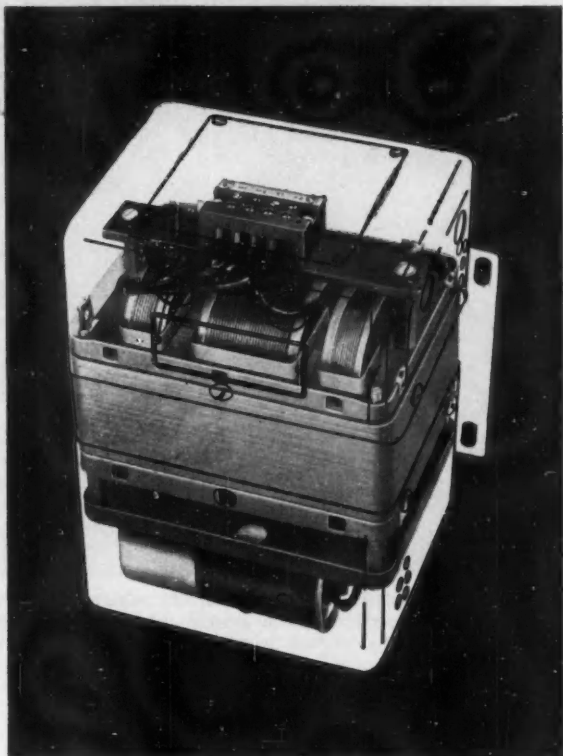
In the past, military applications of compensated motors have far exceeded industrial applications. However, with industry's new emphasis on higher accuracy and faster response, the compensated dc servo motor is finding more applications there. Some recent examples are steel mill drives and machine tools.

A direct price comparison between compensated motors and conventional shunt motors cannot be made, because costs vary considerably over the range of available machines. In general, however, the prices of compensated motors are higher than their conventional shunt equivalents because of their special construction and shorter production runs. The price differential extends from 10 percent in the larger hp ratings to more than 100 percent for the smaller sizes. It should be noted that, as discussed above, the use of the compensated types often makes it possible to get along with a smaller frame size for a given load. This could make the cost of a compensated drive for a specific application actually less than the cost of an acceptable shunt motor drive of conventional design.

The amount of compensation is determined by the motor designer and is usually on the order of 80 to 100 percent, depending on the performance and load conditions specified by the user.

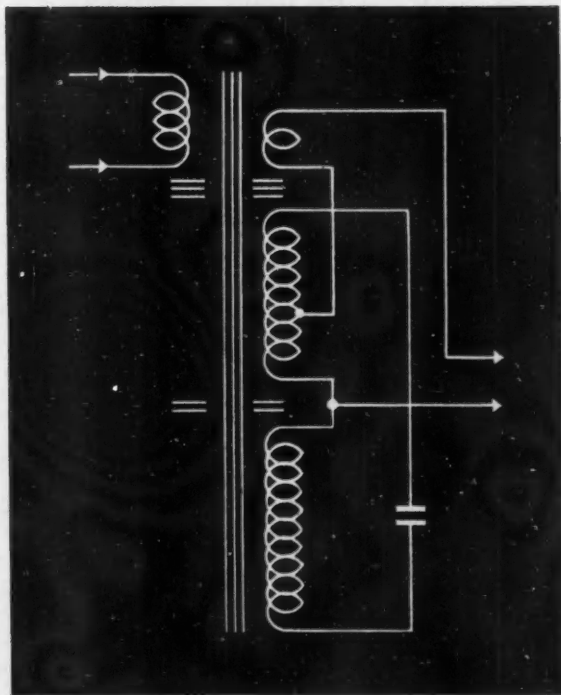
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Phantom view shows simplicity of Sola design. Note absence of components requiring maintenance such as motors, gears, contactors, tubes and relays.

Schematic diagram indicates the complete reliance on static elements. This is the circuit of a representative Type CVS regulator which delivers output having less than 3% total rms harmonic content.



What's missing in this Sola voltage regulator?



When they designed the Sola Constant Voltage Transformer, what did they leave out? Trouble, for one thing. Original equipment manufacturers and plant engineers know that when you build in simplicity, you build out maintenance headaches.

The two illustrations at the left show clearly the Sola's few parts and straightforward design. This compact simplicity is possible because Sola regulators employ static-magnetic methods of voltage control.

The basic Sola design eliminates moving parts, renewable parts, manual adjustments, routine maintenance, and spare parts stock. Because there is nothing to wear out, no tubes to burn out — you know that when you specify Sola voltage stabilization, you automatically specify trouble-free reliability.

Despite this simplification, the Sola gives you these performance benefits: $\pm 1\%$ regulation over input voltage variations as great as $\pm 15\%$, response time of 1.5 cycles or less, protection against short circuits for itself and its load, a high degree of isolation between input and output circuits, and negligible external field. Type CVS (illustrated with typical circuit diagram) delivers a commercial sine wave with less than 3% total rms harmonic content.

Sola static-magnetic units are available for regulation of common line voltages, as well as filament, plate-filament, computer-circuit and variable voltage outputs. They can also be supplied in step-up and step-down ratios to replace conventional non-regulating transformers.

Whether you are developing new electric or electronic equipment, or have a specific voltage regulation problem, your nearest Sola sales engineer will be happy to discuss your requirements with you.

Write for Bulletin 26K-CV



SOLA ELECTRIC CO.

Busse Rd. at Lunt, Elk Grove, Illinois



A Division of
Basic Products
Corporation

Hempstead 9-2800



Starts with Rat Rotor (shown with Technician Nicholas Latrangi) which contains eight white rats, their food and water, bar pressing mechanisms, and sequencing mechanisms. Indications of bar pressings are transmitted to . . .



Control rack composed of 600 to 800 relay boards, each with a stepping switch and general purpose relay. Much of the rack was designed by psychologist Ronald Ray (foreground). From the rack the data are transmitted to . . .

Computers Unfold the Secrets of Human Behavior

In the world's most elaborate automatic laboratory to study operant behavior, the job of handling a mammoth volume of data has been split between a special purpose computer and a general purpose machine. The former analyzes and compresses data; the latter completes the computation.

LEWIS H. YOUNG, Control Engineering

During the past 10 years the study of operant behavior, which used to be of academic interest only, has intensified because experiments in this field now have a valuable payoff in evaluating the effects of drugs on behavior; developing sophisticated, effective methods of instruction such as automatic teaching machines (CtE, June '60, p. 20); and uncovering fundamental information about the human learning process.

Operant behavior is an area of psychology concerned with the actions an individual performs on its environment (anything outside its own body) and covers the bulk of human actions that raise most of the problems in human affairs. Operant behavior includes actions from the wriggings of an infant to an adult's application of reasoning power. Psychol-

ogists have found that if a reward is made dependent upon certain properties of behavior, that behavior tends to increase in frequency. For example, if an animal receives food every time it raises its head past a certain point, the animal will raise its head more frequently. Thus operant behavior, it has been observed, depends on its rewarding or punishing consequences. Conditioned operant behavior is the subject of a variety of intriguing experiments.

Such experiments demand huge quantities of data, collected over relatively long periods of time. One objective of operant behavior experiments in the drug field, for example, is to measure the changes in behavior resulting from the administration of drugs. Psychopharmacologists have already recognized that there are innumerable patterns of behavioral drug effects and that some form of classifying them is needed. If each pattern were reduced

AUTOMATIC OPERANT BEHAVIOR LABORATORY



Magnetic recorder and analyzer. Data are recorded on 20-channel tape, then analyzed and compressed by this special purpose computer (being eyed by Schering's Dr. Francis Mechner). Finally punched cards move to the computer laboratory where. . .



Computation takes place on Datatron under the supervision of Gordon Thomas. Punched tape at side inserts identification information and descriptive data.

to a behavioral index, thousands of such indices could be evolved. From such an accumulation of data could come a classification of drugs as well as improved understanding of behavior.

To handle this flood of data, the Schering Drug Co. has just completed an automatic operant behavior laboratory that will give psychopharmacologists the broadest scope for experimentation. By mechanizing the data gathering and recording procedures, Schering's Dr. Francis Mechner, who heads the operant behavior group, is able to conduct continuous operant behavior studies on animals and humans for long periods of time.

Schering's operant behavior experiments are being carried out with rats, monkeys, and human beings. Using the data from all three types of experiments, Mechner compares the behavior patterns of the animals with those of humans and extends to the human studies the methods and procedures developed in the animal laboratory. Results obtained to date have confirmed the hypothesis that drugs affect the operant behavior of animals and humans in very similar ways.

Mechner's objective at present is to study how operant behavior changes under the influence of drugs. In his experiments he trains a subject to perform a routine of pressing bars or pushing buttons, acts psychologists feel can be generalized to other operant responses such as running or vocalizing, and he measures their performance under normal conditions and after a drug has been administered. Such comparisons reveal the behavioral effects of the drug. With the automatic laboratory, Mechner can make observations over the period dur-

ing which the drug has an effect.

In a typical experiment the subject has access to one or more bars (or buttons) to be pressed according to a set routine such as "press bar A 10 times and then press bar B once." Each time the subject conforms to the routine, it is rewarded. (For the animals, the reward is a drop of water. This is effective because it is the only water they get. For the human subjects, Mechner has discovered that money is a rather effective reward.) Responses are recorded primarily as relay openings or closing and sometimes as the force exerted on the bar. After an experiment has been performed with the subject in normal condition, it is repeated under identical circumstances after the drug to be tested has been administered.

The equipment

To mechanize this procedure Schering has designed three types of special equipment. First, a so-called "rat rotor" was evolved, in which eight white rats spend their entire life. The rotor, which cycles the animals through a testing station automatically and continuously, is a turntable divided by radial walls into eight trapezoidal compartments. A rat at the testing station has access through suitably placed holes and slots to two bars and to the cup of a water dispenser. The test cell also has an array of signal lights which the rat can see through another set of holes.

Each rat stays in the test cell for a scheduled work session. When it is over, the turntable indexes and the next rat is brought into the test station.

The inside wall of each trapezoidal cage has two openings, one through which food can pass and the

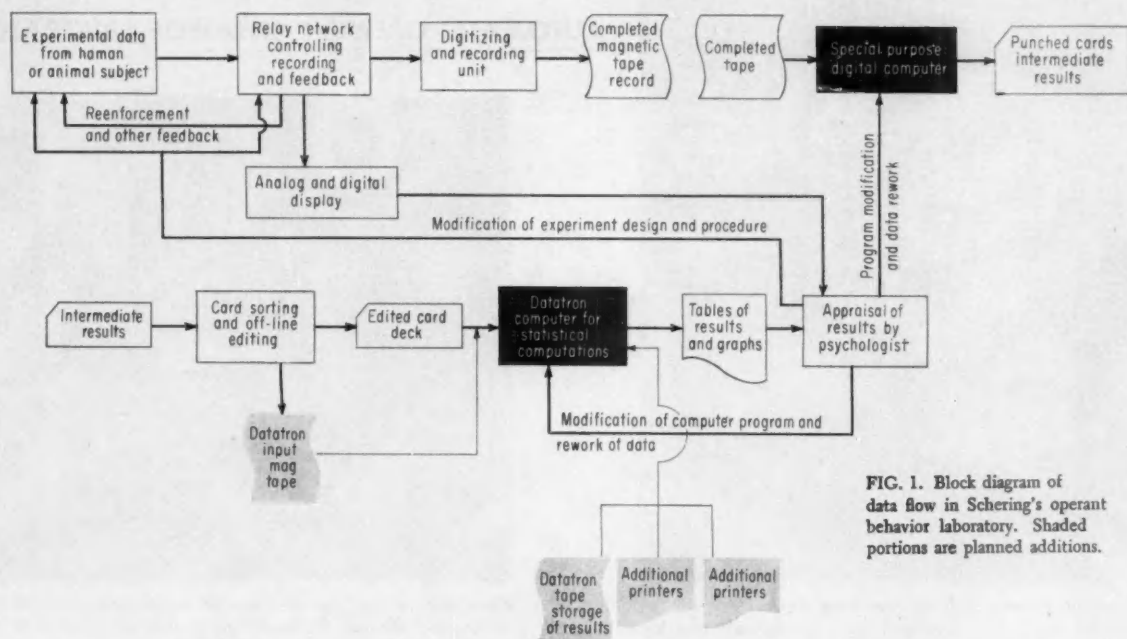


FIG. 1. Block diagram of data flow in Schering's operant behavior laboratory. Shaded portions are planned additions.

other for water. The rat can be fed and watered according to any desired schedule. Normally in an experiment the rat receives his food but he must earn his drinking water by bar pressing.

Second piece of special equipment is a giant control rack, 31 feet long. All the switching circuitry controlling the experimental conditions—timing of feeding, sequencing the stimuli, etc.—is mounted on either side of this rack, which is subdivided into as many locations as there are experiments concurrently underway (the normal number being 18 to 20). Hardware on the rack consists primarily of relays, stepping switches, and timers.

The final special gear evolved in two pieces: magnetic tape collating equipment that collects the data, digitizes it, and records it and a special purpose computer that analyzes the data and converts it to computer format on punched cards to fit a Burroughs Electrodata 205 general purpose computer.

The laboratory currently has 13 rat rotors in operation. Each can be programmed for a different testing cycle—the time from one work session to the next for a given animal—by setting up appropriate timers in the control rack. Normal test cycles are 4, 8, 24, or 32 hr, so that a rat's work session ranges from 30 min to 4 hr. To investigate a drug whose main effects show up within 4 hr, scientists will choose a 32-hour test cycle so that a rat is in the test cell for four hours. To study effects of a drug whose influence will appear over a period of several days, the scientists would select a 4-hr test cycle, sampling the animal's behavior for 30 min every 4 hr for as many days as necessary.

In one rotor the scientists might set up a test that would require the rats to press one bar at least 10 times, then press a second bar once to earn a

drink of water. In another rotor, the pattern might require the rat to press one bar and then wait at least five seconds before pressing a second bar to earn his drinking water reward. All such sequences are set up in the control rack.

In the control rack, which cost about \$7,000 and was built by Schering technicians under the supervision of the psychologists, there are between 600 and 800 relay boards, each board containing a stepping switch and a general purpose relay. Dr. Mechner has stayed with GP relays rather than special purpose ones because such components give him a standard building block that can be used in a variety of ways. From the control rack the data are transmitted to the tape recording device.

At the same time Dr. Mechner records some of the data two other ways. One is with a special analog device called a Kymograph recorder, one for each animal. The recording from this device, an ink tracing, Figure 3, merely indicates every action that takes place and tells the psychologists that the experimental gear is working properly. These records maintain a permanent account of every response or other event.

Another recording system consists of 300 Sodeco impulse counters, remotely resettable, to keep track of the number of bar pressings for each animal and other events that require counting. Mounted close together on one panel, the counters are programmed to be photographed automatically, whenever a reading is required, at rates that vary from every 15 min to a few times a day. On the counters the scientists can also record frequency distributions of time intervals, of run lengths or simple totals of various behavior events. The Kymographs and counters back up the more precise data on magnetic tape.

Schering's special purpose data reduction system was designed jointly by Dr. Mechner, Schering's electronic engineer, J. Knapp, and Digitronics and cost over \$140,000. Its two main parts are both completely transistorized: a recording unit and an analyzing unit. The recording unit takes voltages such as those which are proportional to the force applied in bar pressings or the speed of response, digitizes them into a six-bit binary representation, and records these on 20-channel magnetic tape, 1½ in. wide. In addition, other events indicated as relay closings are recorded.

Special efforts were incorporated to move the tape at very slow speed, at a rate of 1 in. per sec, so that one reel will last 24 hr. 280 bits can be placed on each inch of tape. With its 20 channels, the recorder can handle 20 different experiments at one time. Five additional tracks are available for timing and control.

The analyzing unit is an even more sophisticated device. It is a stored program special purpose computer whose job is primarily one of sorting the experimental data into desired frequency distributions according to various sequential and conditional relationships between the recorded events, then compressing the data sharply and coding them for punched cards—a predigestion of the data.

Playback rate is 100 in. per sec. Each of the 20 tracks is processed separately, one at a time. If a tape were to hold its maximum complement of 20 experiments, that tape would be replayed through the analyzer 20 times.

To specify the kind of analysis applied to the data, a psychologist can program the special purpose device with a 3,264-hole patchboard. This imparts a high degree of flexibility to the analyzer and keeps it relatively simple from an electronic standpoint, an important factor in Schering's thinking because so many of the people who helped develop this equipment and must work with it have no formal electronics background (see box, Schering's Non-electronic Staff). Once a tape is analyzed by the machine, it can be run through a second time and a different kind of analysis performed (if the psychologist changes the patchboard program). This dual, or triple, or even quadruple analysis, is something that just can't be done without automatic equipment because the volume of data generated is too tremendous.

Compressing this volume of data is another job of the analyzer. In a typical 3-hr segment of a recent experiment, the analyzed data amounted to 14,000 14-bit characters which were compressed by the Digitronics machine to fit on 14 80-character punched cards. Typical output of the analyzer: frequency distributions of inter-response times, run lengths, response force, correlograms, sequential analyses, and functions of one variable tabulated against another. Results of the analysis are stored in a 140-word magnetic core memory, each word being a four-digit number.

The punched cards are intermediate data, serving as an input to the general purpose computer, a Burroughs Electrodata machine that also does other scientific problem solving and inventory computations for Schering.

When Dr. Mechner was planning his automatic operant behavior laboratory, he considered the possibility of going directly from the magnetic recording equipment to the GP machine, doing the analyzing on the GP unit. Gordon Thomas, who directs Schering's computer work, estimated that it would take 12 Datatron computers (of the 205 size) to handle the data.

Even with the special purpose Digitronics computer bearing the brunt of the data volume, the Datatron has worked as much as 56 hr to process just 3 hr of compressed data for one rat rotor.

As part of simplifying the procedures on the Datatron computer, Dr. Mechner's group puts certain input information—material such as identifying information and descriptive data—on punched tape which is inserted into the machine when final data punched cards are prepared.

The Datatron then performs such computations as the calculation of averages, standard deviations, medians, correlation coefficients, regression lines, and analysis of variances. They appear both as graphs plotted on an X-Y plotter and as tables printed out.

Because operant behavior experiments are still relatively new, Schering has built a lot of flexi-

FIG. 2. Row of Kymograph recorders which indicate to psychologist that experimental gear is working.



FIG. 3. Trace of a Kymograph recording.

SCHERING'S NONELECTRONIC STAFF

Of the seven men instrumental in the design of Schering's automatic operant behavior laboratory, only two, borrowed from Schering's engineering staff, have had any formal training in electronics.

Dr. A. B. Whitman, who as assistant director of research at Schering administers the laboratory, is a graduate biologist.

Sparkplug of the operant behavior laboratory, of course, is **Dr. Francis Mechner**, who has taken all his formal training in psychology. Mechner conceived the laboratory idea, and devised the rat rotors.

Another psychologist who helped set up the automatic laboratory is **Arthur G. Sapper**, whose introduction to things electronic started when he built an automatic operant behavior laboratory in his apartment, while attending Columbia University.

Responsible for much of the design of the control rack and its operation is psychologist **Ronald Ray**, who earned his master's degree at Columbia University.

Gordon Thomas, who directs the computer operation, has worked as a biologist and a chemist, finally started formal training in mathematics after he got interested in computers at Schering.

The two electrical engineers from Schering's engineering department have worked with the operant behavior group full time for almost two years. They were responsible for the design of the special purpose data reduction system. **Julius Z. Knapp**, an electrical engineer for 15 years, also was largely responsible for the development of the device for recording response force and velocity. **Irving Teich**, an electrical engineer with 14 years experience, supervises the preventative maintenance program for the data reduction system. Chief interest of both men now is in instrumentation for operant behavior research.

bility into the data processing and analyzing procedures. The block diagram (Figure 1) shows how many places the psychologists and computer people may change procedures or programs. For example, the experiment design might be modified as a result of what the psychologist observes on the Kymograph analog displays or after reviewing the photographs

FIG. 4. Human subject under test in behavior booth.



of the counters. After preliminary results are printed out by the Datatron machine, the psychologists might change the analysis program in the Digitronics analyzer or the mathematicians might change the Datatron program.

In Figure 1, the shaded components are those which Schering plans to add to the Datatron installation to improve handling the operant behavior data. Primarily the additions are magnetic tape units and additional high speed printers.

In addition to the studies with rats, Mechner's group has a human operant behavior program underway. For his human experiments, Mechner employs retired Schering employees whose earnings depend on their performance during the studies. In the course of such tests, the subject is trained to do a number of button pushing tasks, and the psychologists measure how well the subject follows a specified routine. For example, in one of the tests, the subject receives $\frac{1}{4}$ cent each time she successfully taps two keys three seconds apart. This is measured before and after the subject receives a drug like a tranquilizer or a stimulant.

The objectives

All this activity has many objectives. From Dr. Mechner's bar pressing studies may come some radical new behavior drugs that will be more specific in their effect. For example, Dr. Mechner points out that some present drugs, like alcohol, have undesirable effects as well as desirable. Alcohol possesses great relaxing qualities, but it has a serious disturbing affect too: mainly it uncoordinates the user. What would be desirable is to develop a drug with the relaxing qualities of alcohol but without the uncoordinating complications. The drug company is also interested in developing new stimulants. Coffee, for example, stimulates very well, but frequently leaves the drinker irritable, impatient, nervous, and unable to sleep. Mechner thinks making more precise measurements of behavior can lead to the discovery of drugs with the good effects and with none of the bad.

Another reason for the laboratory's existence is to learn about the undesirable behavioral effects of experimental drugs sooner. Some of these undesirable reactions are a long time showing up in routine experiments. For example, one antibiotic eventually induced deafness and others tend to make some patients drowsy. And one recent drug even produced color-blindness. These are undesirable side reactions which Mechner could detect before the drug reaches the general market.

Probably the most exciting objective of Mechner's experiments is to discover new kinds of behavior action whose existence is not even suspected. Such knowledge might be able to answer some intriguing questions: Can behavior patterns be changed in ways that are unknown today? Can man be made more intelligent? Can he be made more creative?

Analog setup . . .

1. solves polynomials

2. plots root locus

. . . automatically

LEON LEVINE
Hughes Aircraft Co.

Engineers faced with the problem of analyzing or synthesizing control systems in the frequency domain are usually called upon to obtain the roots of the system characteristic equation. This is an n th degree polynomial of the form:

$$W(s) = a_n s^n + a_{n-1} s^{n-1} + \dots + a_1 s + a_0 \\ = u + jv \quad (1)$$

where

$$s = x + jy = re^{j\theta}$$

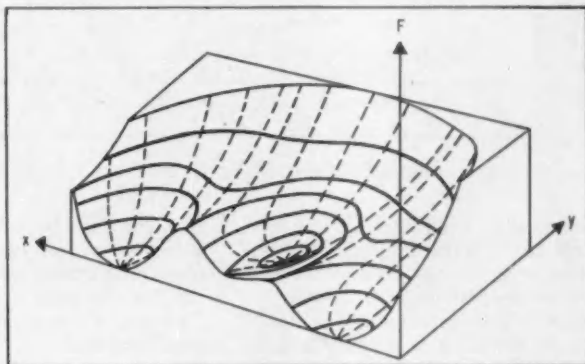
The n roots of the polynomial, s_i ($i = 1, 2, \dots, n$), satisfy the equation:

$$W(s_i) = 0 \quad (2)$$

The coefficients a_k ($k = 0, 1, 2, \dots, n$) are parameters of the system under study and are real valued constants. The roots of the polynomial s_i are either real or complex.

Unfortunately the solution of polynomials by numerical methods is a difficult task in all but the simplest cases, and especially when the degree of the equation is higher than three or four. There have been available several special devices that can factor higher degree polynomials and, in some cases, plot root loci. All of these machines, however, require some participation by the operator. To minimize operator effort, a prototype of an automatic root finding and root locus plotting device using commercial analog computer components was built at the Hughes Aircraft Co. In this machine the polynomial coefficients are set on potentiometers and an arbitrary value of s is chosen. From this starting value the machine varies s until a root has been found, at which time s is held fixed. Once having acquired a root, the machine plots a root locus resulting from a continu-

FIG. 1.
Plot of function $F(x, y)$ in which solid lines represent contours and dotted lines signify gradients.



ous variation of one or more of the polynomial coefficients.

The device employs a method for obtaining the roots of a polynomial that differs radically from that used in all other polynomial solvers. Without exception, other root calculators work directly with some form of Equation 1, altering the value of s until the sum of the terms becomes zero. Quite often it is the operator himself who must determine when the machine has found a root. In contrast, the automatic polynomial solver minimizes a related function whose minima are the roots of the polynomial.

Solution procedure

Consider the function $F(x, y)$ in which x and y are related by the Equation $s = x + jy$. A plot of a typical function is shown in Figure 1 with solid lines representing contours and the dotted lines, gradients. The x and y values of the minima are the real and imaginary components of the roots of the polynomial. From an arbitrary starting point (x_0, y_0) , any path in the xy -plane (s -plane) along which $F(x, y)$ always decreases terminates without exception on a minimum, which is also a root of the poly-

nomial. The rate of decrease of $F(x, y)$ is greatest when the path in the s -plane reduces the function in the direction of its gradient. This optimum path is followed by the automatic root solver and is called a path of steepest descent.

The initial values of x and y and the path along the gradient uniquely determine the minimum at which the path terminates. Different initial values of x and y must be chosen to obtain the other minima. Obviously, several gradient paths converge at the same minimum. Since it takes the machine about 10 sec to find a minimum, all of the roots are obtained in a very short time, even though initial conditions may be chosen so that some of the roots are found more than once in the process.

The shape of $F(x, y)$ and especially its minima are functions of the coefficients of the polynomial. A change in the value of one or more of these coefficients results in a corresponding shift in the position of the minima. Because this polynomial solver is a minimum seeking device, it can plot the root loci by following the path of variation of the minima. The machine begins the root locus plot at

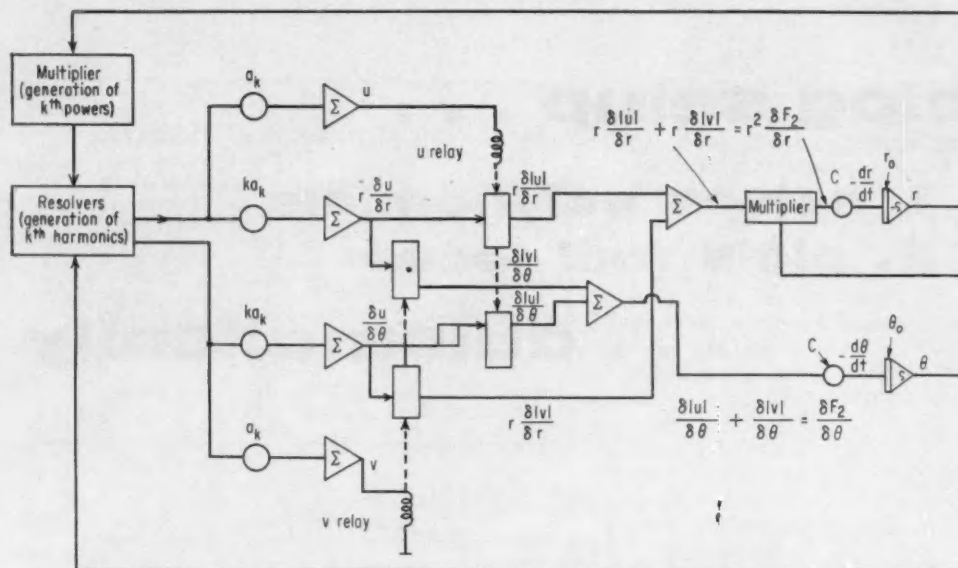


FIG. 2. Block diagram of automatic device for finding polynomial roots and plotting root loci.

a minimum. A change in the coefficients displaces the minimum, and the device seeks its new position along a path of steepest descent. If the coefficients vary continuously and slowly enough, the machine follows the path of the minimum without error and, thereby, traces the root locus.

Note that this method permits plotting any root locus no matter how the polynomial coefficients vary. By contrast, the Evans root locus technique, an extremely useful graphical procedure, requires that the characteristic equation be put in the form:

$$1 + K \frac{b_m s^m + b_{m-1} s^{m-1} + \dots + b_1 s + b_0}{c_n s^n + c_{n-1} s^{n-1} + \dots + c_1 s + c_0} = 0 \quad (3)$$

The root loci are plotted for a variation of K , a special way in which the polynomial coefficients can change.

Instrumentation

The basic equations for a path of steepest descent (Ref. 4 gives detailed explanation) in the s -plane are simpler to instrument when expressed in polar coordinates. The equations are:

$$\frac{dr}{dt} = -c_1 r^2 \frac{\partial F}{\partial r} \quad (4), \quad \frac{d\theta}{dt} = -c_2 \frac{\partial F}{\partial \theta} \quad (5)$$

These equations are stable for all values of r and θ and assure that r and θ vary continuously along the gradient path. The negative sign establishes a descending path, and c_1 is an arbitrary constant determining the rate of descent.

The key to the successful operation of the root solver is furnishing a suitable function to be minimized. This

function must be nonnegative for all values of s and have minima that occur only at points where $F = 0$ and that are the roots of the polynomial. Two simple functions fulfilling these conditions are:

$$F_1 = u^2 + v^2 \quad (6), \quad F_2 = |u| + |v| \quad (7)$$

where u and v from Equation 1 are expressed in polar coordinates as:

$$u = \sum_{k=0}^n a_k r^k \cos k\theta \quad (8)$$

$$v = \sum_{k=0}^n a_k r^k \sin k\theta \quad (9)$$

Function F_2 is chosen because it has a larger gradient than F_1 in the neighborhood of a root. For F_2 Equations 4 and 5 become:

$$\frac{dr}{dt} = -c_1 r^2 \left[\frac{|u|}{u} \frac{\partial u}{\partial r} + \frac{|v|}{v} \frac{\partial v}{\partial r} \right] \quad (10)$$

$$\frac{d\theta}{dt} = -c_2 \left[\frac{|u|}{u} \frac{\partial u}{\partial \theta} + \frac{|v|}{v} \frac{\partial v}{\partial \theta} \right] \quad (11)$$

where

$$\frac{|u|}{u} = +1 \quad \text{for } u \geq 0$$

$$\frac{|u|}{u} = -1 \quad \text{for } u < 0$$

and

$$\frac{|v|}{v} = +1 \quad \text{for } v \geq 0$$

$$\frac{|v|}{v} = -1 \quad \text{for } v < 0$$

The additional equations required are

$$r \frac{\partial u}{\partial r} = \frac{\partial u}{\partial \theta} = \sum_{k=1}^n k a_k r^k \cos k\theta \quad (12)$$

$$- \frac{\partial u}{\partial \theta} = r \frac{\partial v}{\partial r} = \sum_{k=1}^n k a_k r^k \sin k\theta \quad (13)$$

The task of instrumenting these equations in the polynomial solver is simplified because of the similarity of u , v , and the partial derivatives. Observe, for example, that each of the terms comprising u in Equation 8 need only be multiplied by an integer k to obtain the corresponding terms in Equation 12.

Figure 2 shows how the polynomial solver solves Equations 10 and 11 simultaneously. The two relays sense the sign of u and v . In solving for a root the operator sets the initial values for r and θ and the output of integrators 1 and 2. Switch 1 is closed and r and θ vary until a root is reached. At this point, if the polynomial coefficients are changed continuously, the root locus can be plotted from the corresponding values of r and θ .

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How to Find Emergency Air Needs for Pneumatic Instruments

F. CAPLAN, Kaiser Engineers

Here's an original and useful nomograph designed to provide a quick means for finding the emergency capacity of air receivers used to supply instrument air.

TYPICAL PROBLEM

Suppose a paper plant had the following instrument air requirement:

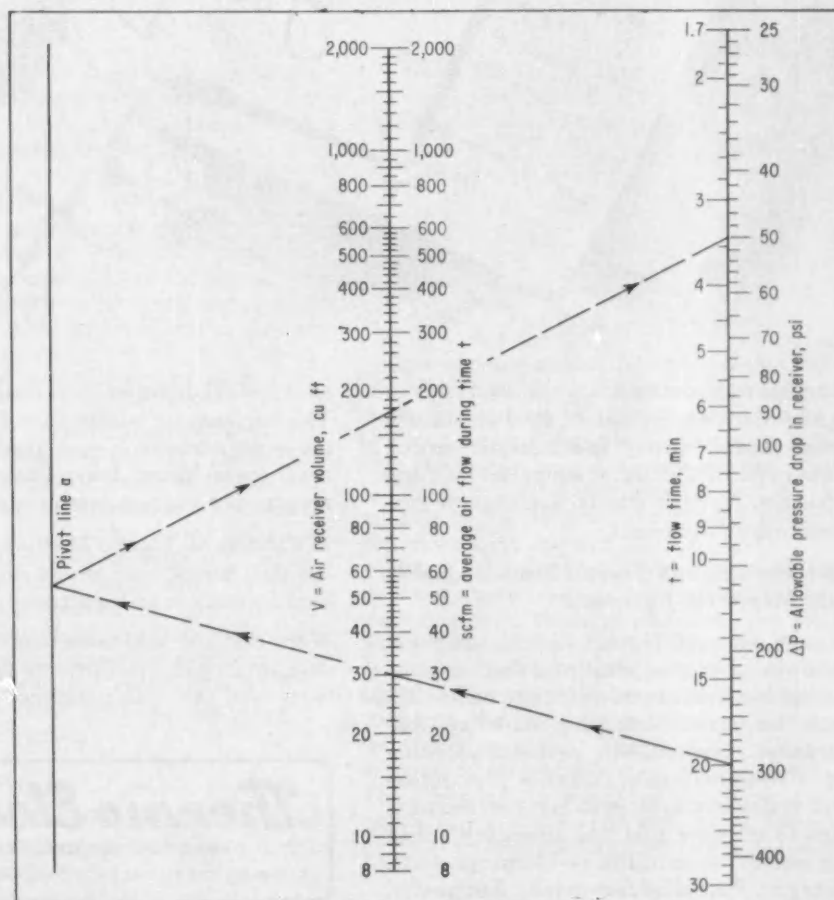
1. Recorder-controllers (temperature, flow, level, and consistency).....24.0 scfm
2. Blind controllers (pressure)..... 0.5 scfm
3. Electropneumatic transmitters 3.0 scfm
4. Valve operators and positioners..... 2.5 scfm

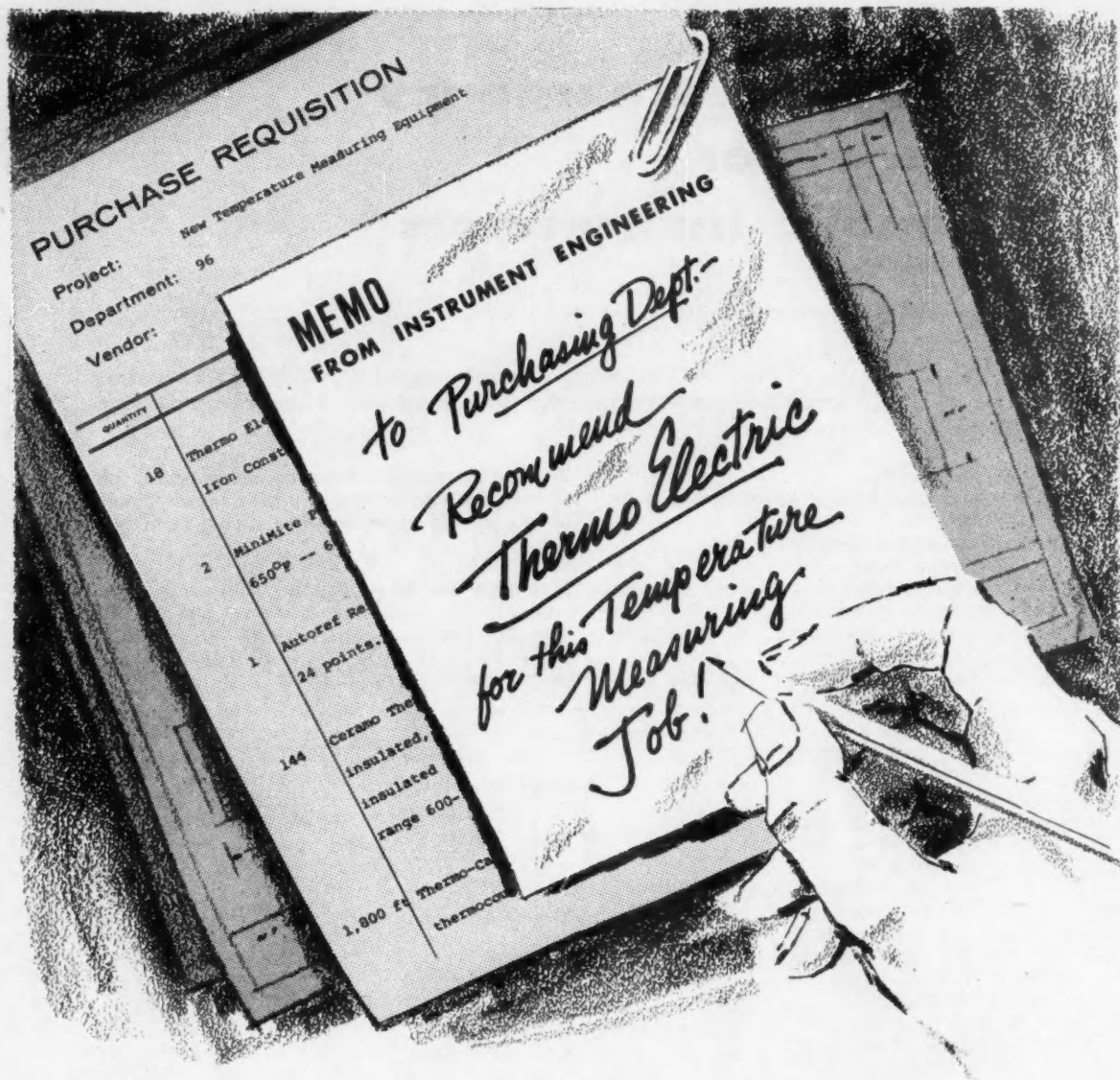
Total consumption30.0 scfm

Find the air receiver volume required to permit this consumption rate for 20 min. with an initial pressure of 110 psi and an allowable minimum of 60 psi.

SOLUTION:

First align time ($t = 20$ min) with average flow rate (30 scfm) and continue to pivot line *a*. Then align this point on *a* with allowable pressure drop ($\Delta P = 110 - 60 = 50$ psi). Read volume required on center scale ($V = 176$ cu. ft.)





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OPTIMUM RESPONSE RELAY SERVOS

Part III: Higher Order and Related Systems

THE GIST: In the second part of this series (July 1960, pp. 77-84), author Lewis described several ways in which the optimum response switching criteria may be applied, within the limits of present-day hardware, to the design of first and second order relay servos. Here he concludes the series with a discussion of two additional types of systems: third order systems which, like the second order systems, use switching operations, and a relatively recent group of systems in which no switching is performed.

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Up to this point in the discussion of optimum response relay controls, no systems higher than second order have been considered. Many output member types, however, cannot be adequately described by any of the transfer functions mentioned in Parts I and II of this series.

The first difficulty encountered in going to third or higher order systems is loss of the phase plane as a tool for describing the kinematics of the system. Of course, a reasonable geometric interpretation of third order systems is still possible. This involves the use of a three dimensional space (e vs \dot{e} vs \ddot{e}) in which switching occurs at a particular surface rather than at a point.

Efforts at designing workable third order systems fall into two general categories according to whether 1) the theoretically optimum system is synthesized or 2) some approximation of optimum conditions is used. It may be recalled that for second order systems, the approximation dealt primarily with instrumentation of the switching boundaries. For third order systems the approximation frequently involves not only approximations of the switching surface but also the use of one switch operation instead of the two required from theoretical considerations (Ref. 23). Both types of third order systems are considered briefly in this section.

Theoretically optimum

As a simple example of the response of an idealized third order system, assume that input motor torque

is a linear function of time (i.e., no torque limit) and that torque rate dT/dt equals KV . For an output member with inertia only,

$$J \frac{d^2 e}{dt^2} = T$$

or

$$J \frac{d^2 e}{dt^2} = dT/dt = \pm KV,$$

and, for a step input,

$$J \frac{d^2 e}{dt^2} = -dT/dt = -KV \quad (24)$$

In this case the output member transfer function takes the form, $1/s^3$. Figure 18 shows, for a step input, the ideal response of this system as a function of time; the two torque rate reversals occur at $t_{1,2}$ and $t_{1,3}$. The system accelerates to a maximum velocity for the first half of the transient and decelerates similarly during the second half so that error and all derivatives go to zero at $t_{1,2}$.

The switching sequence for an ideal third order system is associated with three sections of the complete trajectory. Working backwards, the third and final section consists of a zero trajectory, the second section is a trajectory in the switching surface which contains the zero trajectory, and the first section goes from the initial point to an intersection with the switching surface. This is shown schematically in Figure 19 without reference to any specific system. The algebraic signs of e , \dot{e} , and \ddot{e} correspond to those shown in Figure 18. The first torque rate reversal occurs at x where the trajectory intersects the switch-

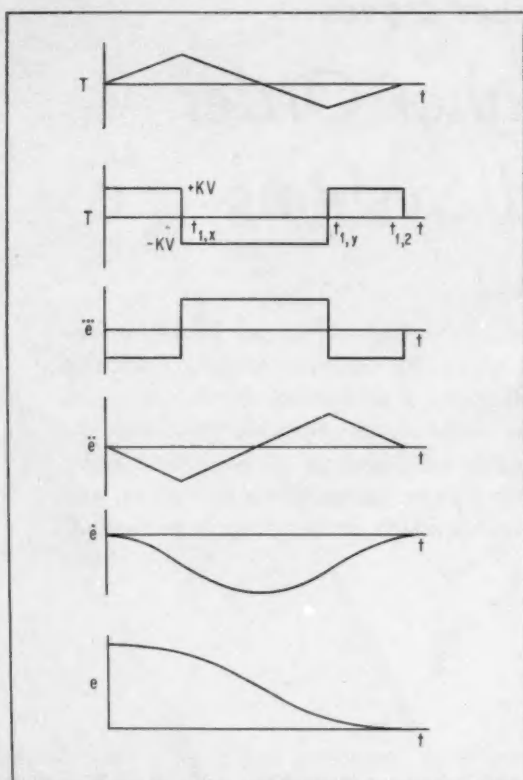


FIG. 18. Ideal response of a typical third order system to a step input.

ing surface; the second occurs at y at the zero trajectory.

The two-fold problem of designing a third order optimum system involves 1) deriving equations for the switching surface and the zero trajectory and 2) instrumenting these equations in the form of a controller which supplies the switching function to the relay. One method (Ref. 23) of deriving the switching criteria uses normal coordinates instead of e , \dot{e} , and \ddot{e} and involves projections of the switching curves on planes of the three-dimensional phase space. Another method (Refs. 59, 24, 27) requires direct solution of the differential equation as was done for the second order systems, although this sometimes becomes difficult. A technique for finding the switching curves on an analog computer has also been described (Ref. 60). In this case, the independent variable t was replaced by minus t , and the equilibrium conditions at the origin were used as initial conditions.

Instrumentation of the switching surface requires a two-variable function generator or some similar computation in which the switching function is found from e , \dot{e} , and \ddot{e} inputs (Ref. 24). One analog study used an electro-optical arrangement in which a photoelectric tube counted pulses generated by interrupting

a light beam with lines on a rotating disc (Ref. 59). One input positioned the light beam; the other controlled duration of the counting interval. Output was an analog voltage proportional to the number of pulses counted per revolution of the disc. In another study (Ref. 60) a set of masks over an oscilloscope screen added a third dimension to the similar two dimensional method described in Part II. Because of imperfect switching, the ideal switching criteria are modified in practical systems to obtain a region of proportional control near the origin. As mentioned in the first part of this series, computing techniques which require \ddot{e} as an input are quite susceptible to noise problems.

In a recently published method for synthesizing third order systems, the optimum switching function has been replaced by a linear combination of e , \dot{e} , and \ddot{e} , so that the surface becomes a plane (Ref. 61). This simplifies the instrumentation, and curves derived from an analog computer study show the nature of the variation of optimum adjustment as related to the step input amplitude.

Useful approximations

The difficulties associated with instrumentation of optimum third order systems have led several investigators to seek approximations which require only one switching operation in addition to final signal removal. One method (Ref. 30) uses the energy balance technique for deriving the modified switching criteria; in this case the third order system operates with one period of acceleration, one of deceleration, and a final period with no forcing. It settles to an equilibrium condition in a manner which is almost optimum. Another approximate technique involves "open circuit switching", so that for a third order system \ddot{e} and higher derivatives go to zero at the switching instant (Ref. 62). This permits use of an e - \dot{e} plane representation of the switching boundaries, since each new section of a trajectory starts in this

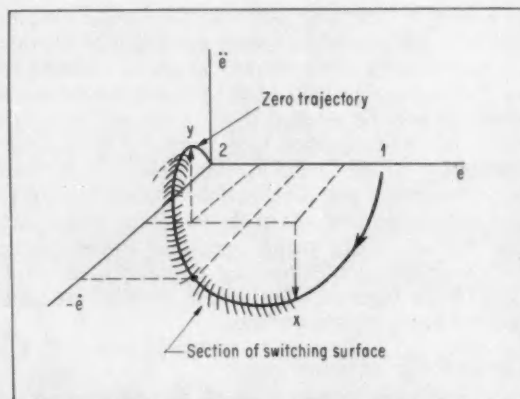


FIG. 19. Phase-space representation of the switching sequence for an ideal third order system.

plane. Instrumentation, therefore, becomes much simpler. The switching boundary in this case is a curve in the $e-\dot{e}$ plane which is the locus of initial conditions ($e, \dot{e} \neq 0, \ddot{e}, \dots = 0$). A trajectory starting from this locus passes through the origin of the phase space, and only one reversal is necessary. A third approximate method (Ref. 63) uses one reversal controlled by a switching boundary in the $e-\dot{e}$ plane plus a small linear zone near the origin. Coordinate transformations derive the switching boundary which is similar to that of a second order system; for an output member of the form $1/[s^2(Ts + 1)]$, the boundary equation becomes

$$2e + (|\dot{e}|^2 + 4T|\dot{e}| + T^2) \operatorname{sgn} \dot{e} = 0 \quad (25)$$

Finally, modifications to the absquare control of Equation 16 (Part I) have been suggested for third order systems, and test results have substantiated the value of such methods (Ref. 27).

Although the theory of optimum relay control of higher order systems has been fairly well established, the complexity of the resulting designs makes satisfactory approximations highly desirable. The foregoing has described several systems in which the switching operation is retained. The following section discusses some of those systems which attempt to approximate optimum response without the use of a switching device.

Related systems—Nonswitched

In the systems discussed so far, the goal of minimum-time response was achieved (in ideal cases) by driving the controlled member to its limits at all times by switching the applied input at the proper instants. Imperfections associated with the switching operation frequently resulted in undesirable characteristics. Within the past several years, a number of investigators have suggested various types of nonlinear control systems in which no switching operation is required, and many of these have been capable of a performance which approaches that of an optimum system. Usually such systems have been adjusted for best response to a step input.

One group of such systems makes use of different arrangements of RC networks and varistors. These are inserted in cascade with the controlled member. For example, variable gain and variable time constant networks have been used to alter open-loop transfer functions and thus obtain an improved transient response (Ref. 64). Circuits using variable- μ vacuum tubes and similar active elements are also well known. One approach using modern network synthesis techniques involves the design of a linear network whose output has zeros in time corresponding to the required switching instants when the input is the error signal (Ref. 65). This is similar to computing σ or γ , the switching control functions. The network output drives a saturating power amplifier so that a signal something like $\pm KV$ is applied to the output motor.

Another method of designing for improved transient response is to alter an originally linear differential equation. For second order systems, damping or gain or both may be changed as a function of error; examples of this technique applied to switched systems have been cited. For nonswitched systems, variable damping has been used for an equation of the form:

$$\ddot{e} + f(e)\dot{e} + Ke = 0 \quad (26)$$

In general $f(e)$ should increase for decreasing error. One suggested form (Ref. 19) may be written:

$$f_1(e) = \frac{b}{1 + a|e|} \quad (27)$$

where both a and b are constants. Another form (Ref. 66) is:

$$f_2(e) = m - n|e| \quad (28)$$

Caldwell and Rideout (Ref. 67) show that, for step

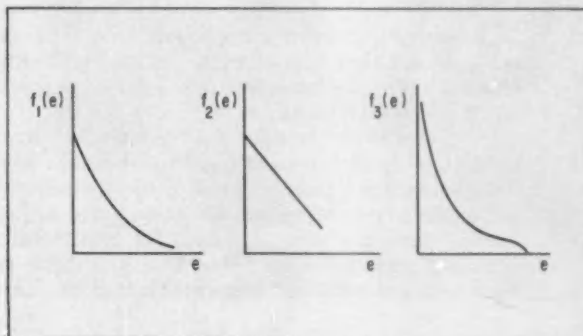


FIG. 20. Three variable damping functions.

inputs, this type of damping gives nearly optimum response. A more general approach to this type of design starts by deriving equations of trajectories in the phase space which approximate optimum trajectories (Ref. 68). Required functions in the differential equation are then obtained from these. For a second order system subjected to a step input, a differential equation like Equation 26 is used and one resulting $f(e)$ takes the form:

$$f_3(e) = K \sqrt{\frac{e_{1m}}{e_1}} \sqrt{\frac{e_1}{|e|} - 1} \quad (29)$$

where e_1 is the initial error and e_{1m} its maximum allowable value. This system has a theoretical response time just 11 percent greater than that of the corresponding optimum system. The error functions which produce variable damping (those given by Equations 27, 28, and 29) are shown in Figure 20. Note their similarity. A system based on Equation 29 was built and tested and provided good agreement with results that were predicted (Ref. 69).

The phase-space synthesis method can also be

used for higher order systems. For example, for a third order system, the differential equation is:

$$\frac{d^3 e}{dt^3} + h(e) \frac{d^2 e}{dt^2} + a_1 \frac{de}{dt} + a_2 e = 0 \quad (30)$$

where $h(e)$ is similar to $f_3(e)$ when plotted. A considerable amount of study has also been carried out on a system described by the third order equation:

$$\frac{d^3 e}{dt^3} + b_1 \frac{d^2 e}{dt^2} + g(e) \frac{de}{dt} + b_2 e = 0 \quad (31)$$

where $g(e)$ equals $K_1(1-K_2e^2)$, and numerical values of parameters needed for good control have been found from computer studies (Refs. 70, 71).

These few examples show that nonswitched as well as switched systems should certainly be considered in trying to develop a nonlinear control which approaches the optimum. The approximations in both types of systems and the small loss in performance characteristics may be well worth the gain that is available in system simplicity.

Conclusions

Nonlinear systems of the optimum relay type certainly cannot answer all of today's control problems. However, two very important facts justify continued interest in such systems.

First, the study of optimum systems has been partially responsible for a stepped-up interest in nonlinear systems in general. The departure from linear techniques in control system design and analysis has opened many new areas of activity for control engineers and renewed interest in such classical fields as mechanics and nonlinear differential equations. This

interest, coupled with the aid of modern analog and digital computers, has been quite stimulating. The whole field of control engineering has gained greater understanding of its problems and their solutions.

Secondly, in those systems whose inputs are reasonably close to steps or ramps, direct application of the ideas of optimum control is possible. Certainly nonlinear systems of the future will be capable of responding in an optimum manner to other inputs, e.g., periodic and random inputs.

One recent survey (Ref. 72) suggests three areas of activity which require further effort: theoretical analysis, experimental analysis, and practical application. Following are several specific topics that merit particular attention.

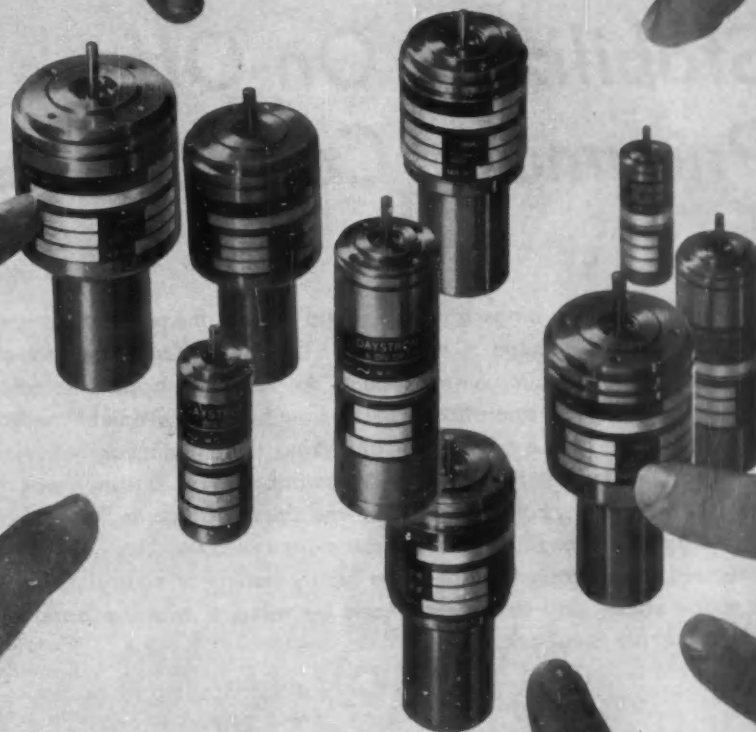
- ▶ further study of higher-order systems
- ▶ optimum design for other inputs
- ▶ studies on practical compromises—particularly on computing switching functions
- ▶ application of digital techniques
- ▶ design of special circuits and hardware for direct application in optimum systems

In relation to trends in the broader area of nonlinear control, it is interesting to note that today the great increase in the study of adaptive control systems (Ref. 73) places more emphasis on the flexibility of a control system so that a wider range of plant or output member characteristics can be accommodated. On the other hand, optimum control has generally been restricted to specific forms requiring very high quality transient response. No doubt combinations of these concepts will appear at a future time.

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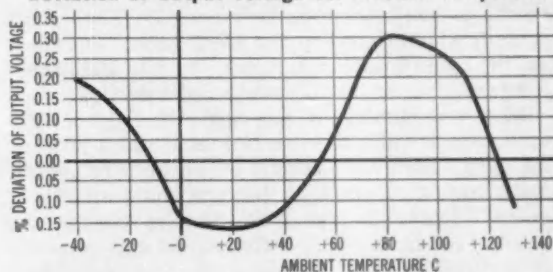
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Stabilizing On-Off Pneumatic Control Systems

On-off elements and air as a working fluid are, by themselves, not unusual. But they are rarely found in combination in high performance control systems. On-off pneumatic control systems do, however, appear to offer the advantages of good operational performance and convenient mechanical design—in spite of the difficulty of analyzing their nonlinear behavior.

To prove the feasibility of on-off pneumatic control a study was made for the Stratos Div., Fairchild Aircraft and Engine Corp. of the control system for a turbojet engine variable area exhaust nozzle. The system analysis presented here concludes that these highly nonlinear control systems can be made stable and suitably damped by using a two-deadband control valve and rate feedback.

KARL EKLUND, Wyle-Parameters, Inc.

Analysis of this control system proceeds in four steps: deriving the equations describing the components, combining these into an over-all system equation, solving this equation for each set of conditions—thus forming basic phase-plane trajectories, and combining the basic trajectories into a composite phase-plane plot representing system behavior.

The control system for the jet engine nozzle is shown in semiblock form in Figure 1. The components whose characteristics affect system behavior are the control valve, the motor, the rate and error computer, the air supply, and the inlet ducting.

Most complicated of the elements, the control valve, consists of a flow control valve and a reversing valve. Both valve sections are operated by pneumatic control signals from the rate and error computer. Because of the fairly complex pneumatic balance conditions, it is necessary to approximate their behavior by a simplified description. The reversing valve is regarded as having a deadband equal to that of the smaller of the two flow control valves. When actuated to be outside this deadband, the reversing valve produces a flow direction corresponding to the sign of the input signal s . For signals inside the deadband, both sections of the reversing valve are open to a very low pressure.

The flow control valve has two orifices with different areas. These are opened by poppet valves with different deadbands, the smaller orifice having

the smaller deadband as shown in Figure 2. When air flows through the valves in a forward direction, the orifices produce a pressure drop depending on the open areas. In the reverse flow direction—when the motor has overshoot and is trying to pump air back into the supply—both valves open and full supply pressure is applied to the motor. This is a result of valve design and low atmospheric pressure.

The air flow through the valve is:

$$\left(\frac{dM}{dt}\right)_v = \frac{8.02 A P_s}{(RT)^{1/2}} \left[\frac{k}{k-1} \left[(P/P_s)^{1/k} - (P/P_s)^{(k+1)/k} \right] \right]^{1/2}$$

where

$(dM/dt)_v$ = theoretical air mass flow rate, lb/sec
 A = orifice area, sq ft.
 P_s = inlet (supply) pressure, psia
 P = outlet (duct) pressure, psia
 k = ratio of specific heats = 1.4 for air
 R = gas constant = 53.3 for air
 T = gas temperature, deg Rankine

This equation is valid only for outlet pressures greater than a critical value of pressure which corresponds to the maximum value of the radical. Below the critical value the outlet pressure is constant.

The equation can be reduced to simpler form:

$$\left(\frac{dM}{dt}\right)_{\text{valve}} = 2.16 \frac{A}{A_0} \frac{P_s}{P_0} (T_0/T)^{1/2} f(\alpha) \quad (1)$$

where $\alpha = P/P_0$

and

$P_0 = 222$ psia
 $A_0 = 0.16$ sq in.
 $T_0 = 530$ deg R

The function $f(\alpha)$, a normalized flow function, is

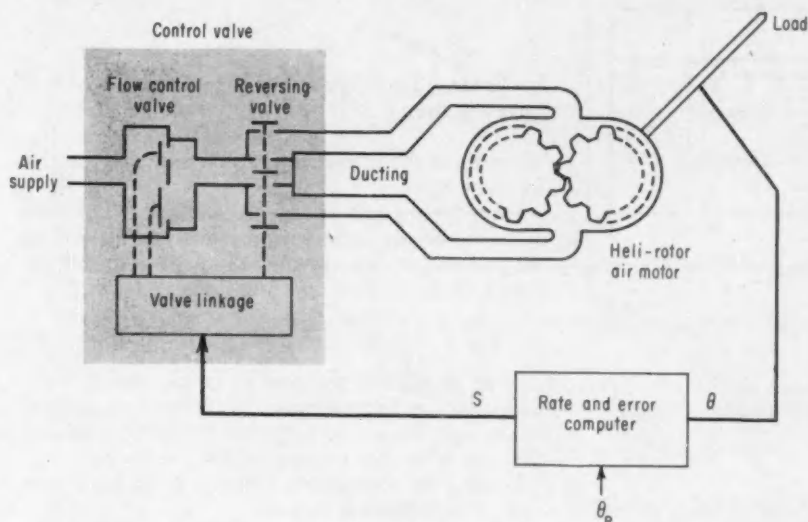


FIG. 1. On-off pneumatic control system for positioning variable area exhaust nozzle of a turbojet engine.

given in Figure 3 along with $f(a)/a$, which appears later in the analysis. This form assumes a flow coefficient (ratio of actual to theoretical flow) of 0.6. In the analysis $P_s = P_0$, $T = T_0$, and A can take on the values $A_L = A_0$ and $A_s = 0.0183A_0$.

The Heli-rotor motor is an air driven rotary machine similar in action to a gear-type pump driven backwards as a motor. It is assumed to have a torque proportional to differential pressure and independent of speed. The assumption is correct to within 5 percent. Like a gear pump, the motor has a constant swept volume per revolution. For the motor chosen the particular values were:

$$\tau = 314 \alpha \text{ in.-lbs}$$

$$V/\theta = 1.04 \times 10^{-5} \text{ cu ft/rev}$$

Using the ideal gas law, the air density is:

$$\rho = \frac{P}{T_0 R} = \frac{P_s}{T_0 R} = 1.08 \alpha \text{ lb/cu ft}$$

Then the mass flow rate through the motor is

$$\left(\frac{dM}{dt} \right)_{\text{motor}} = 1.13 \times 10^{-5} \alpha \frac{d\theta}{dt} \text{ lb/sec} \quad (2)$$

The value of the net torque is needed to calculate the output acceleration. If the load is retarding, then the acceleration is:

$$\ddot{\theta} = \frac{\tau - \tau_L}{I} = [\alpha \text{sgn}(s) + \alpha_L \text{sgn}(\dot{\theta})] \quad (3)$$

where

$$I = \text{load inertia} = 0.02$$

$$\alpha_L = \tau_L/314$$

$$\text{sgn}(s) = \text{arithmetical sign of error signal}$$

$$\text{sgn}(\dot{\theta}) = \text{arithmetical sign of output velocity}$$

The two operations for sign are put into the expression so that the pressure ratio a and the effective back pressure of the load α_L can be assumed positive.

Valves of α_L as used in the analysis were chosen for simplicity of calculation, since the actual loads could only be estimated. In a jet nozzle the load is partly frictional, which is always retarding, and partly aerodynamic, which is a unidirectional force

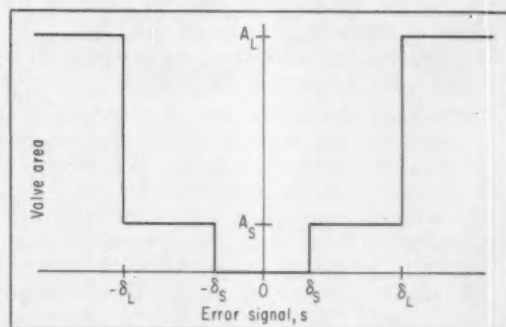


FIG. 2. Flow control valve with two deadbands.

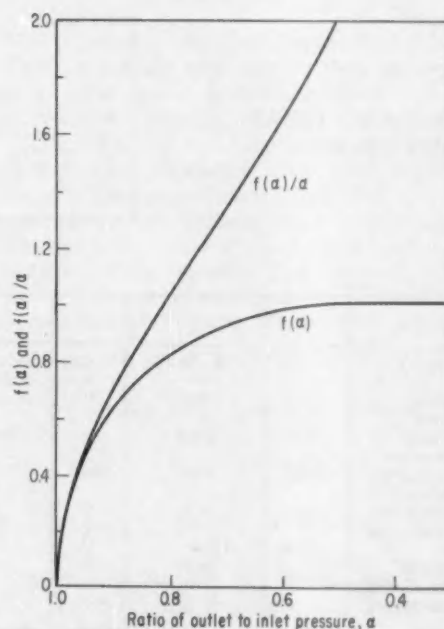


FIG. 3. Normalized flow functions.

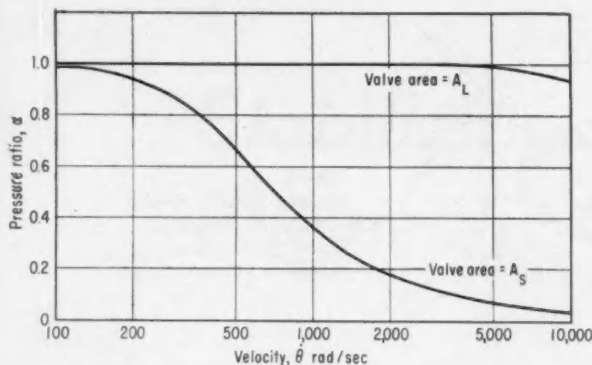


FIG. 4. Equilibrium values of pressure ratio as a function of motor speed and valve opening.

acting to open the nozzle. These were estimated to be about the same in magnitude and for the analysis were assumed to be exactly the same and equal to 112 lb-in. Thus in the closing direction $\alpha_L = 0.7$, while in the opening direction the two load components just cancel and $\alpha_L = 0$.

The rate and error computer is also a pneumatic device, but to simplify the analysis it is assumed to

be linear. Its output (the signal to the control valve) is thus:

$$s = (\theta - \theta_R) + a\dot{\theta}$$

where θ_R is the reference position and a is the rate feedback ratio.

Inlet ducting acts like an accumulator. The mass of air stored per second was assumed to depend on the pressure as given by the ideal gas law so that for a duct 1½ in. in diam and 3 in. long,

$$\left(\frac{dM}{dt}\right)_{\text{duct}} = \frac{P_0 V}{RT} \frac{d\alpha}{dt} = 1.09 \times 10^{-8} \frac{d\alpha}{dt} \text{ lb/sec} \quad (4)$$

The air supply was assumed to be of constant pressure, independent of flow. If this is not a good assumption it can be corrected by using a smaller effective valve area to account for line drops.

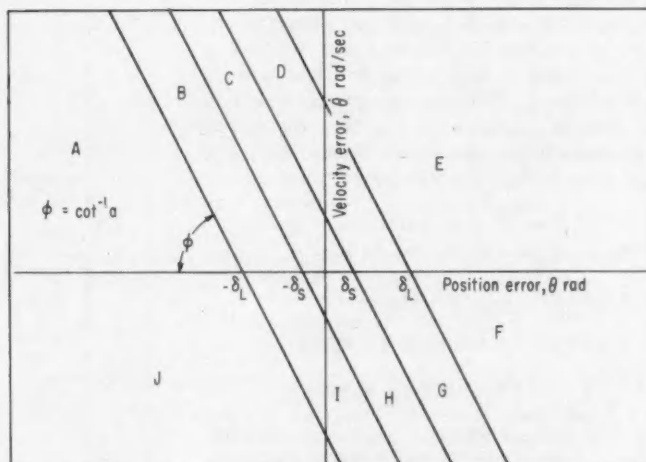
Uniting the component equation is the basic principle of conservation of mass:

$$\left(\frac{dM}{dt}\right)_{\text{duct}} = \left(\frac{dM}{dt}\right)_{\text{valve}} - \left(\frac{dM}{dt}\right)_{\text{motor}}$$

As a specific example of finding velocity and position as needed for analysis, consider the case where the error is large and motion is in the opening direction. The system equation becomes:

THE 10 PHASE PLANE REGIONS . . .

. . . AND WHAT THEY MEAN



REGION	A	B	C	D	E	F	G	H	I	J
Error signal (s)	$s < -\delta_L$	$-\delta_L < s < \delta_S$	$ s < \delta_S$	$\delta_S < s < \delta_L$	$\delta_L < s$	$\delta_L < s$	$\delta_S < s < \delta_L$	$ s < \delta_S$	$-\delta_L < s < -\delta_S$	$s < -\delta_L$
sgn (s)	-	-	±	+	+	+	+	±	-	-
Flow control valve area	A_L	A_S	0	A_S	A_L	A_L	A_S	0	A_S	A_L
Control valve flow direction	Fwd	Fwd	0	Rev	Rev	Fwd	Fwd	0	Rev	Rev
Reversing valve position	Fwd	Fwd	Open	Rev	Rev	Rev	Rev	Open	Fwd	Fwd
Pressure ratio (α)	1	$\alpha(\theta)$	0	1	1	1	$\alpha(\theta)$	0	1	1
Back pressure (α _L)	0	0	0	0	0	0.7	0.7	0.7	0.7	0.7
sgn (θ̇)	+	+	+	+	+	-	-	-	-	-
"Accelerating" pressure - [α sgn (s) + α _L sgn (θ̇)]	1	$\alpha(\theta)$	0	-1	-1	-0.3	$0.7 - \alpha(\theta)$	0.7	1.7	1.7

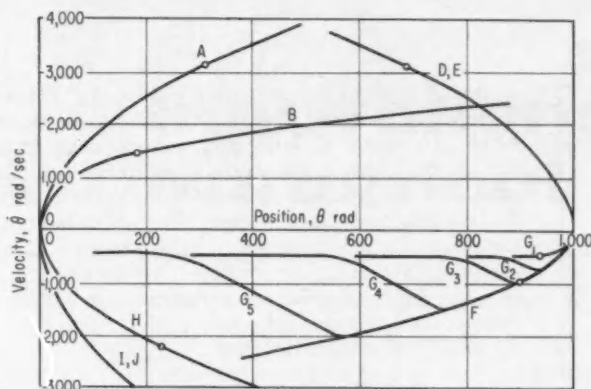


FIG. 6. Basic phase-plane trajectories appropriate to the 10 regions shown in Figure 5.

$$1.09 \times 10^{-6} \frac{d\alpha}{dt} = 2.16 f(\alpha) - 1.13 \times 10^{-4} \alpha \int_0^t 1.57 \times 10^4 \alpha dt$$

Over a short time interval the integral (which represents motor velocity) very nearly equals zero and can be neglected. It is only necessary to consider the pressure rise in the duct caused by flow through the valve. Then:

$$1.09 \times 10^{-6} \frac{d\alpha}{dt} = 2.16 f(\alpha)$$

A numerical integration shows that the pressure rise is complete in a period on the order of microseconds. This means that the duct pressure reaches equilibrium instantaneously for all practical purposes, and the system can be described by merely equating the flow through the valve to the flow through the motor:

$$\frac{2.16}{\alpha} \frac{f(\alpha)}{A_0} = 1.13 \times 10^{-4} \theta \quad \text{forward flow}$$

$$\alpha = 1 \quad \text{reverse flow}$$

This can be simplified further since the larger valve opening has little drop. Figure 4 shows the equilibrium value of α as a function of motor speed and valve opening. The upper curve indicates that the pressure drop across the large valve area can be ignored. These simplified equations result:

$$\frac{f(\alpha)}{\alpha} = 2.86 \times 10^{-6} \theta \quad \text{small area, forward flow}$$

$$\alpha = 1 \quad \text{large area, forward flow}$$

$$\alpha = 1 \quad \text{reverse flow} \quad (5)$$

The proper values of α can then be used to find the acceleration from:

$$\ddot{\theta} = -1.57 \times 10^4 [\alpha \operatorname{sgn}(s) + \alpha_L \operatorname{sgn}(\dot{\theta})] \quad (3)$$

Then one integration yields velocity, and a second integration yields position, needed to plot the phase-plane trajectories.

Basic phase-plane trajectories

Because of the nonlinearities due to the discontinuities associated with on-off devices and with compressible flow through orifices, the phase-plane method was chosen for the analysis of the system. The phase-plane presentation offers the

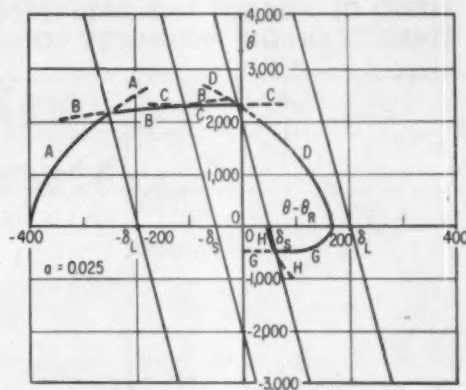


FIG. 7. The system phase-plane plot is constructed by matching the velocities of the basic trajectories. Rate feedback equals 2.5 percent.

opportunity to consider variations of the system parameters with a minimum of recalculation. In this technique the phase trajectory, the plot of output position vs output velocity, is displayed with time entering only as a parameter. Basic trajectories in various regions of the phase plane can be calculated and combined graphically. The usual method of display is to assume an initial position (or velocity) error and see if the system attains an equilibrium position corresponding to zero velocity and error.

Equations 3 and 5 are used to calculate basic phase trajectories for the 10 regions of the phase-plane shown in Figure 5. Each phase region corresponds to a particular set of conditions as listed in the table.

Note that except for regions B and G, in which the torque depends on the pressure drop across the small valve area, $d^2\theta/dt^2$ is a constant. Thus:

$$\dot{\theta} = \dot{\theta}_0 + \ddot{\theta} t$$

$$\theta = \theta_0 + \dot{\theta}_0 t + \frac{\ddot{\theta} t^2}{2}$$

The trajectories for these conditions are shown in Figure 6, labeled according to their appropriate region. The circled points correspond to a time of 0.2 sec from a standing start (i.e., $\theta_0 = d\theta_0/dt = 0$).

The remaining two trajectories can be calculated by numerical integration. The basis for this technique is the approximation that, over a small time interval, α (and therefore $\ddot{\theta}$) is relatively constant. Thus an initial value of $d\theta/dt$ yields a corresponding value of α from Equation 5 or Figure 4. This then permits calculating a value of $d^2\theta/dt^2$ from Equation 3, and from that a new value of $d\theta/dt$ by using:

$$\dot{\theta}_1 = \dot{\theta}(t_0 + \Delta t) = \dot{\theta}_0 + \ddot{\theta}_0 \Delta t$$

so that

$$\theta_n = \theta(t_0 + n \Delta t) = \theta_{n-1} + \dot{\theta}_{n-1} \Delta t$$

and

$$\dot{\theta}_n = \dot{\theta}_{n-1} + \ddot{\theta}_{n-1} \Delta t$$

where

$$\ddot{\theta}_{n-1 \text{ avg}} = \frac{\ddot{\theta}_{n-1} + \ddot{\theta}_n}{2}$$

This step by step calculation yields the phase trajectories for the regions B and G shown in Fig.

TWO DEADBANDS AND RATE FEEDBACK STABILIZE ON-OFF PNEUMATIC CONTROLLER

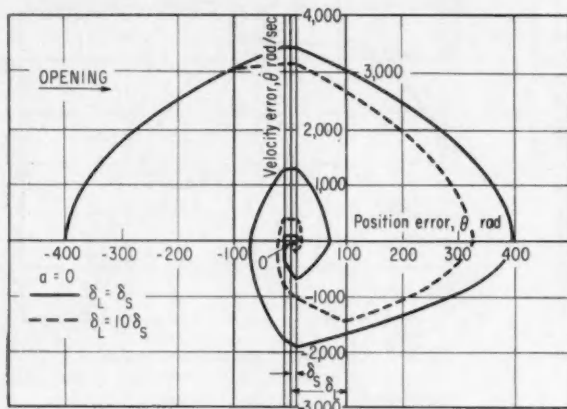


FIG. 8. System phase-plane plot with one and two deadbands and no rate feedback.

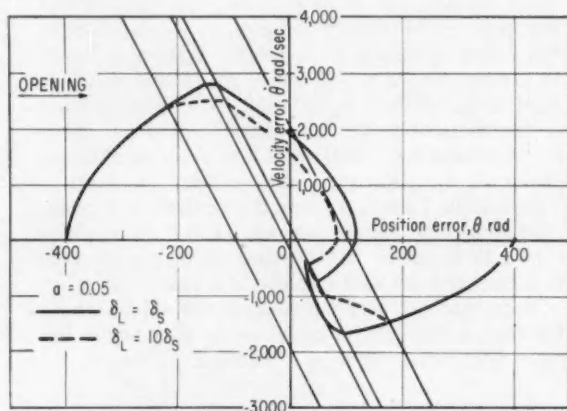


FIG. 9. System phase-plane plot with one and two deadbands and rate feedback of 5 percent.

ure 6. The several trajectories shown for region G correspond to selected values of initial velocity. Trajectories for other initial velocities can then be constructed by graphical interpolation. Note that the trajectories for region G all attain a steady speed when the load back pressure and the valve pressure drop just equal the supply pressure. In region B this does not occur because there is no net load.

Because the trajectories in any case depend only on velocity, they can be combined graphically by matching velocities as the trajectories enter into a new region or set of operating conditions. Figure 7 illustrates how basic trajectories are combined to form the system trajectory. Here the system starts out with a position error of minus 400 radians and a zero velocity error, putting the system in region A. Hence trajectory A (from Figure 6) is extended until the system enters into the wider of the two deadbands and the system switches into region B. Trajectory B is then plotted, starting at the velocity

attained by A at the switching condition. B continues until it arrives at region C, the smaller deadband. In region C both flow control valve areas are closed, there is no accelerating force, and the position error decreases at constant velocity. Thus the system coasts until it enters the other limit of the inside deadband, necessitating a corrective force in the reverse direction corresponding to condition D. The graphical construction continues in a similar manner until the final trajectory attains a zero velocity inside the smaller deadband.

Interpreting the plots

Figures 8 and 9 are typical phase-plane plots for the system. They differ in that Figure 8 has no rate feedback ($a = 0$) and Figure 9 has some rate feedback ($a = 0.05$). Each figure is also arranged to show the behavior with variation of deadband ratio. That is, each shows system trajectories for $\delta_L = 10\delta_S$ and $\delta_L = \delta_S$. The condition $\delta_L = \delta_S$ would be obtained by using a simple single port valve instead of the two-step valve postulated in the analysis.

Each system plot can be used to consider the effect of loading on system stability by looking only at the upper or lower parts of each graph. Then several conclusions can be drawn. First, a system with no retarding load is unsatisfactory unless rate feedback is used, no matter whether simple or two-step valves are used. This can be seen from the upper halves of both figures (which correspond to no load in the opening direction). Without rate feedback the overshoot was 100 percent for the simple valve and 80 percent for the two-step valve, while with 5 percent rate feedback the overshoots were 29 and 20 percent, respectively.

Second, when there is a substantial retarding load, either rate feedback or two-step valves (or both) can provide reasonably damped operation. This can be seen from the lower halves of both figures (corresponding to retarding load in the closing direction) where even without rate feedback the overshoot using the simple valve was only 18 percent, and it was reduced to 5 percent by using the two-step valve. In both cases 5-percent rate feedback produced over-critical damping, as can be seen by the absence of overshoot.

Other detailed conclusions can be drawn from such system phase-plane plots. The results can be summarized qualitatively by saying that two-step valves and rate feedback have advantages, but they differ in the situation of best application. The two-step valve can be used to make a relatively fast acting system without excessive overshoot if there is a reasonable retarding load (as seen from the lower trajectory in Figure 8), while rate feedback can make even an undamped system relatively stable (as shown in the upper trajectory in Figure 9). As indicated by the same trajectory, a combination of rate feedback with two-step valves having a large area ratio and deadband ratio can be used to stabilize any system, no matter how intractable it is.

Innovations In Numerical Control

Design highlights of four novel machine tool controls selected from a group of recently announced new and revised systems.

1. Transistorized contouring system features detachable director

P. H. McGARRELL
Thompson Ramo Wooldridge Inc.

The Thompson Ramo Wooldridge numerical machine tool control is an analog-digital system commanded by a punched paper tape input. Like other path controllers, the TRW system requires the use of a director, whose function is to convert intermittent position commands into continuous control signals for the positioning servos. To date, there has been some conflict of opinion on whether the director should be designed as a separate piece of equipment located away from the production area or built into the machine control itself. Most control builders have espoused one approach or the other. The TRW director, however, is available in both integral and independent forms. In the latter configuration, the output of a common central tape reader and director is recorded on magnetic tape. At each machine tool site a magnetic tape playback unit and servo electronics subsystem perform the control function.

Regardless of the type of director employed, the flow of information through the control is the same.

System Inputs

The input numerical information is the result of a straight line synthesis of tool center path around the contour to be machined. Tolerance requirements dictate the number and length of the straight line segments. Specifically, the numerical information for a given straight line segment is a set of five-digit numbers, one for each component axis to be controlled. Each five-digit number denotes the number of 0.0001-in. units of motion required for a given axis to contribute its component to the excursion of the straight line segment.

Numerical data are punched into paper tape in data blocks. Each block contains an appropriate set of five-digit motion numbers, referred to as change orders, along with auxiliary and feed rate control data. All such information is punched, along with a parity check, onto 1-in. eight-channel tape employing binary coded decimal (1-2-4-8) code. Information on tape is transcribed into the director one line at a time by means of either a mechanical or photoelectric reader, depending on the reading speeds demanded by the application.

As each character is read into the director from tape, it is converted into a 1-1-2-5 decimal code. The latter code proves convenient in an important internal pulse generation digestion process to be explained later. In addition, because internal coding is decimal, one-to-one correlation exists between a given character from the input tape and that same character as it progresses through the system. The logic of maintenance procedures is, thereby, greatly simplified over that involved in systems with decimal input but straight binary internal coding.

The process by which the director converts tape data into continuous signals is shown in Figure 1. The feed generator transmits to the feed matrix a variety of fixed frequencies scaled down from the input oscillator frequency. Under control of the feed rate information in active storage, the feed matrix selects and combines these to provide a single appropriate frequency input to the contour generator.

In a mode of operation similar to that of the feed generator, the contour generator, on the basis of its input frequency, transmits a variety of pulse patterns to the contour matrix. Each pattern contains a fixed number of pulses. No pulse in any pattern is time coincident with a pulse in any other pattern, and the total number of pulses from all patterns for each digestion process is exactly 100,000. Note that

FIG. 1.
Block diagram of TRW
director, which can be
furnished separately or as
an integral part of the
machine control.

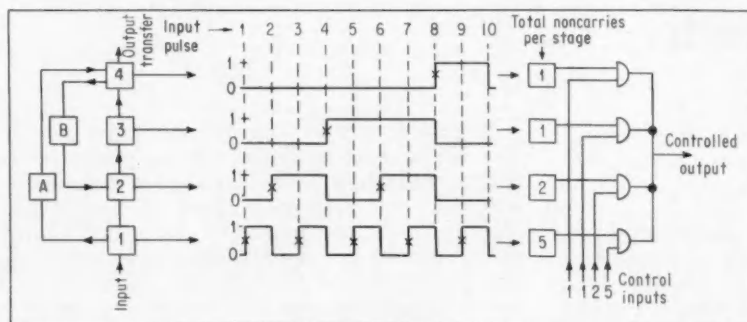
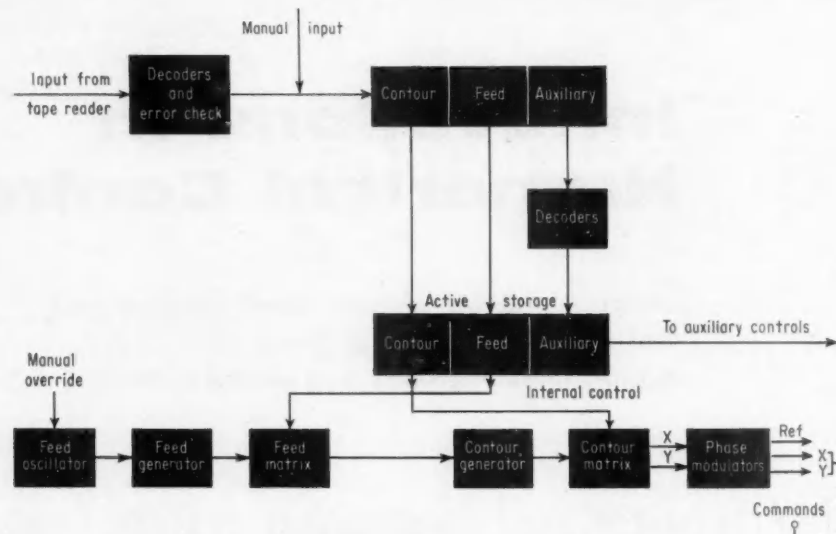


FIG. 2.
Schematic diagram of decade
counter used for pulse gen-
eration.

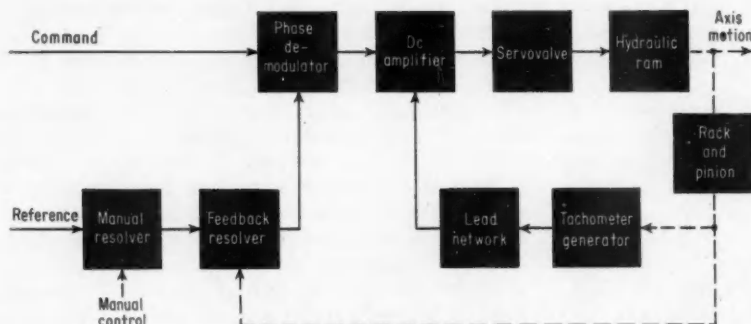


FIG. 3.
Phase demodulator is link be-
tween digital output of direc-
tor and analog signals from
the feedback resolver.

the time interval over which this fixed number of pulses occurs is determined by the contour generator variable frequency input, which is controlled, via the feed matrix, by the feed information in active storage. This time is the digestion interval.

The contour matrix, also under control of active storage, selects for each axis a certain number of pulses from the 100,000-pulse input. For each axis, the output of the contour matrix is a smooth flow of pulses, each representing 0.0001 in. of movement. The total selected pulses for a given axis equal the five-digit number for that axis in active storage, considering that number as a whole number. Thus,

a stored value of 1.0134 in. would result in 10,134 pulses. By manually varying feed oscillator frequency, the operator can override feed rate control in a wide range from below to above tape programmed value.

Pulse generation

More detail is in order concerning the pulse generation process referred to above. This process involves the feed oscillator, generator, and matrix, as well as the contour generator and matrix. Figure 2 shows the ordinary binary-decimal decade counter that is the heart of this process. The decade consists of flip-flops cascaded in a binary counting array.

Decade operation is achieved through feedback loops A and B that permit straight binary counting through nine input pulses, but reset all stages at the tenth.

Waveforms opposite each flip-flop show the pattern of output conditions through a range of 10 input pulses. Also shown for each stage is the total number of "noncarries" (0 to 1 transitions) for a total of 10 input pulses. The 1-1-2-5 notation means that, for 10 input pulses, the output of the respective counter stages is one, one, two, and five pulses.

Note that in Figure 2 one and only one pulse occurs at a given time. Thus, the selection of these output pulses can conveniently be accomplished by means of gates, one in each flip-flop output line, whose outputs are connected to form a single-wire output. Further, since the output transfer pulse from a decade does not produce a "noncarry" in that unit, decades can be cascaded in normal counting fashion with all gates interconnected.

The number or frequency of the pulses from the decade output can be controlled by proper selection of these gates. Such selection is used first in the feed generation system in which a digitally controlled variable frequency is required. In the contour generator and matrix, the same process is used to generate a digitally controlled number of pulses. The details of both the feed and contour generation process can now be described.

The feed system is quite straightforward. The feed oscillator, mentioned earlier, drives counting decades having gates in their "noncarry" outputs. The outputs of the first decade are 0.1, 0.1, 0.2 and 0.5 of the input frequency. Thus the 1-1-2-5 coding, which is held in active storage for controlling the feed system, can produce a frequency range from 0.1 to 0.9 of the input frequency. As an example, an output frequency that is 0.8 of the input is generated by selection of the 0.1, 0.2, and 0.5 gates. Additional decades effect finer control. Two decades, for instance, permit a range from 0.01 to 0.99.

The output of the feed system is a digitally-controlled frequency, which serves as the input to the contour generator and matrix. The contour subsystem consists of five similar decades having interconnected "noncarry" gates and cascaded in a normal decimal counting array. During each digestion interval, pulses from the feed system are accepted until the five-decade counter has counted through its full capacity of 100,000 pulses. All these pulses

reach the lowest order counting decade; 10,000 pulses reach the next decade; 1,000 pulses reach the third; etc. Because each decade provides to its respective buffered gates, one, one, two, and five pulses for each set of 10 input pulses, the lowest order decade generates 1,000-1,000-2,000-5,000 and so on, with the highest order decade providing 1-1-2-5 pulses. Thus, the total number of pulses selected from the initial set of 100,000 can be controlled, in one-pulse steps, by a five-digit, 1-1-2-5 code in active storage.

Drive servos

The final operation in the direction process for each data block is that of phase modulation. In this operation, occurring simultaneously with the pulse generation just described, only the form of command information is changed. Each pair of pulses for a given axis produces a fixed 0.72-deg phase shift in a 200-cycle square wave associated with that axis. Final output of the director is a set of these square waves, one for each axis of control, plus a common reference square wave.

The command signals are now in a convenient analog form to permit use of standard servo positioning techniques. A block diagram of the servosystem is shown in Figure 3 for one controlled axis. Feedback signals originate from resolvers coupled to the drive mechanism. As shown in Figure 3, the excitation for the feedback resolver is derived from a manual resolver, which is also excited by the common reference signal from the director.

The phase demodulator continuously compares feedback resolver output phase with director command phase and generates an output voltage whose magnitude and sign are a direct indication of phase difference. This voltage, suitably amplified, energizes an electrohydraulic servovalve controlling the oil flow to a hydraulic ram or motor. The servo loop causes the output motion to track the desired motion by continuously seeking a null between command and feedback resolver phase. Note that a phase difference between command and feedback resolver phase can also be effected through positioning of the manual resolver which supplies the excitation phase to the feedback unit. A means is thereby provided for manually positioning each controlled axis.

The author respectfully acknowledges the assistance of C. W. Haydl and C. E. Hallmark, both of the Dage Div., Thompson Ramo Wooldridge Inc.

2. Coded Air Cylinders Control Table Position

KENNETH D. GARNJOST
Moog Servocontrols, Inc.

Most, if not all, of the numerical control systems presently available depend heavily on electrical-electronic equipment for their operation. The new

Moog system, however, employs only pneumatic and hydraulic circuitry, from the tape reader right through to the power servos. The first application for this point-to-point positioning control is a Burgmaster turret drilling machine. The experimental system consists of a two-axis work table positioner

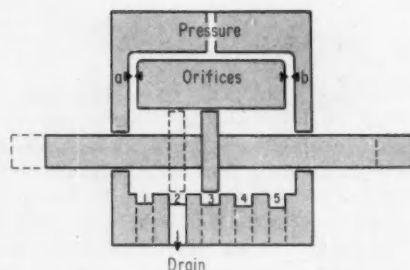


FIG. 4.
Schematic diagram of
hole-seeking piston.

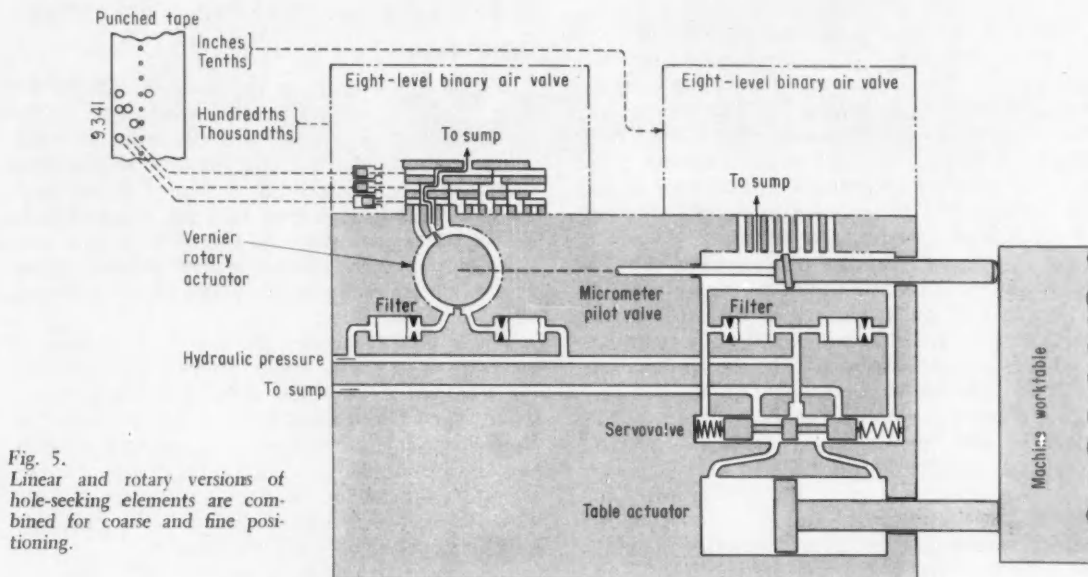


Fig. 5.
Linear and rotary versions of
hole-seeking elements are com-
bined for coarse and fine posi-
tioning.

and a block-type tape reader for standard 1-in., 8-channel punched tape. The tape is read pneumatically, and the resulting air pressures operate selector valves that define the desired position of the hydraulically powered controller. The only electrical signals used in the system are those required to provide tool selection and spindle feed sequencing. The tape reader console also contains manual dials that may be used as an alternate to tape input.

Operation of the positioner is based upon the hole-seeking piston shown in Figure 4. This device functions as follows: If a hole, such as No. 2, in the piston wall is opened to drain, the hydraulic pressure in the left end of the cylinder drops to zero. The resulting pressure difference causes the piston to move to the left until it reaches a position indicated by the dotted line. At this point the flow of high-pressure oil through orifice a is restricted by the closing of drain port 2 and the resulting increase in the pressure in the left end of the cylinder. Since the width of the piston is made slightly less than the diameter of the drain hole, the pressure in the right end of the cylinder decreases as the piston becomes centered over the drain hole. Thus, the piston tends to seek a position at which the leakage to drain, and consequently the pressures on either

side of the piston, are equal.

It is seen that the piston always moves to null on any single hole in the cylinder wall that is connected to drain. Therefore, it can be made to serve as a numerical positioner by providing a means for selecting any of a series of holes in the cylinder. The accuracy of such a positioner under no load is determined only by the accuracy of location of the drain holes; and its resolution is limited only by the number of holes. It is theoretically possible to build a cylinder of any desired length and having 1,000 holes per inch by distributing the holes in a spiral pattern around the cylinder wall. Such a cylinder, with an appropriate number of selector valves, would be capable of discrete positioning in 0.001-in. increments. However, the cylinder and valving would be too complicated for practical machine control.

In the actual control system shown schematically in Figure 5, the degree of complexity is reduced to a practical level by using a basic cylinder having only 10 holes to the inch. This cylinder can position a worktable along one axis of movement in 0.1-in. increments. Selection of the drain holes is accomplished by an eight-level binary selector valve, whose various levels are shifted directly by air passing through holes in the tape. The holes represent

two binary coded decimal numbers indicating desired machine position to inches and tenths of an inch. Interpolation to 0.001-in. increments between the 0.1-in. positions is obtained by rotating the piston. The latter has a helical valving land so that as it is rotated it shifts axially to maintain a null position over the hole. This angular positioning of the piston is done by means of a vernier rotary actuator employing the same hole-seeking principle and having 100 selectable positions. This actuator is also under control of a valve operated from the hundredths and thousandths digits coded on the punched tape.

As pointed out above, the accuracy of this positioning method is determined essentially by the accuracy of location of the cylinder porting holes, and can be practically held to better than plus or minus 0.001 in. However, if the actuator is required to develop a differential pressure to operate against a load, this basic accuracy cannot be maintained. Therefore, in the Moog positioning system, this

cylinder is used not as an actuating element, but as the pilot stage for a conventional spool-type servo-valve. This controls the flow of high-pressure fluid to a ram that moves the machine worktable.

As shown in Figure 5, worktable position is sensed by the micrometer pilot valve, which then becomes a servo-driven, hole-seeking piston. Whenever the pilot valve is not nulled on the particular hole that is ported to drain by the selector valves, a differential pressure is developed to operate the servovalve. Therefore, when the worktable is positioned at the desired point, there will be equal pressures on either side of the micrometer pilot valve piston. The unequal areas of the pilot valve piston result in a net force which loads the pilot valve piston rod against the worktable. Angular positioning of the micrometer pilot valve can be accomplished directly by a rotary hole-seeking actuator because the friction load in this case is low and extremely precise angular positioning is not required.

3. Prepunched Keys Permit Rapid Setup of Drum Programmer

F. P. CARUTHERS, Specialties, Inc.

The design objectives behind the "Specialmatic" machine tool control were to provide the advantages of automatic numerical positioning, while preserving for the talented machine operator the responsibility for "managing" the machine. Features of the system are dial-in controls for feed rate and position, a photoelectrically read drum-type programmer for sequencing all steps in the machining cycle, and a transistorized logic section.

The program sequence is established by inserting prepunched stainless-steel keys, Figure 6, into a rotating drum. A tab on the end of each key shows what particular function it is coded to initiate. Approximately three dozen different keys can program any machining cycle a three-slide turret lathe is capable of. Seven photocells are used to read the holes in the keys. There are seven possible hole locations, one of which checks that the light source is adequate and that the key is properly inserted. The remaining six hole positions are divided into two groups of three each. Each group has eight variations that, when connected to a binary-to-decimal converter, yield any digit from 0 to 7.

The key serves only to establish a particular logic pattern in the control circuitry and does not operate functions directly. Thus, any combination of slide movements and machine functions may be programmed simultaneously. For instance, a key called "End Cycle Normal" moves all three tool slides clear of the workpiece, stops the spindle, applies the

spindle brake, turns off the coolant, and resets the dial selector (a stepping switch) so that the next end-point called for will be on dial 1 on each slide.

One of the primary functions of the program drum is to connect the individual positioning dials for each axis into the circuit one at a time. In a turret lathe application 16 positioning dials are assigned to the turret, while the crossslide and carriage have eight each. Each dial, Figure 7, is composed of a coarse position transducer (left hand side) which is detented to give steps of $\frac{1}{2}$ in. each, a fine position transducer (right hand side) to interpolate between $\frac{1}{2}$ -in. increments, and a feed control potentiometer in the center. When the outside knob is in position shown, only the fine transducer moves. When the knob is pushed in, the coarse transducer turns to rapidly change the desired position. The entire range of travel of the slide is covered in less than six turns by use of the coarse-fine system. Each dial is calibrated in divisions of 0.001 in. and, the end points of motion may be changed by 0.0001 or 0.0002 in. by interpolating between these divisions. The feed rate and traverse control permits continuous feed rate control from 0 to 30 in. per min and a rapid traverse up to the maximum capacity of the pump (approximately 400 in. per min).

Sequential Inductive Transducer

The feedback transducer consists of a stainless steel housing and movable core composed of alternate north and south magnetic sections. The housing contains a number of windings so arranged that as the core moves through it, a series of four

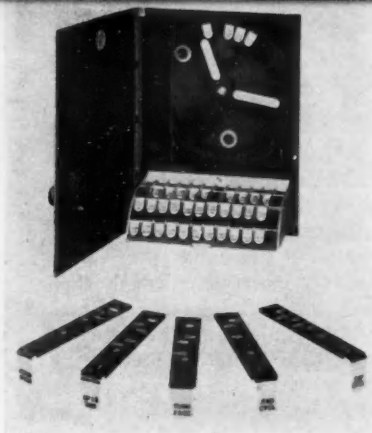


FIG. 6. Prepunched keys are inserted into indexing drum for programming machine operations.

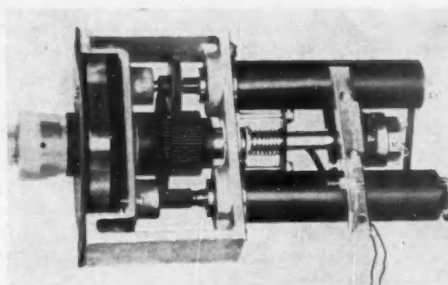
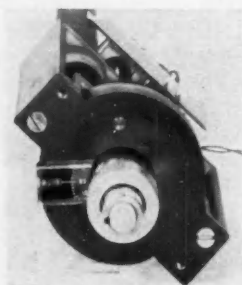


FIG. 7. View of positioning control dial shows coarse and fine command voltage generators and potentiometer for regulating feed rate.

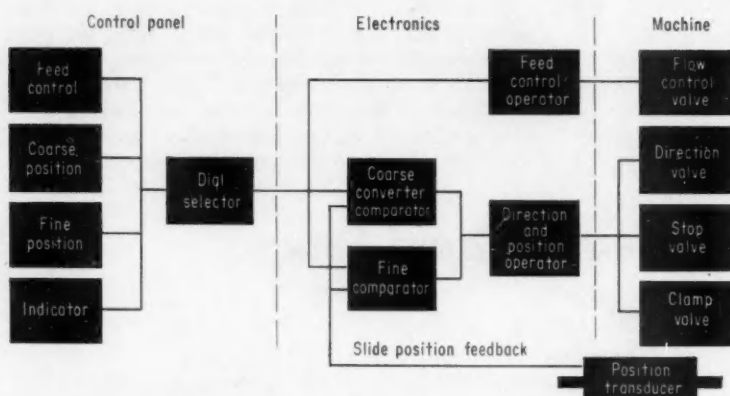


FIG. 8. Block diagram of positioning servos for dial-in control.

equally spaced voltage waves are produced. After each 2-in. movement the magnetic parts of the core are in such a position as to repeat the cycle. Coarse position measurement in any axis involves counting the number of voltage peaks, one for every $\frac{1}{2}$ in. of travel. The count is cumulative so that the register used in the logic section maintains a record of where the slide is at any particular moment. Fine position measurement within any $\frac{1}{2}$ -in. increment is made by selecting one of the voltage waves that is linear for that particular interval and comparing its instantaneous value with the fine command voltage.

Relatively long lengths of travel may be obtained with accuracies and repeatabilities associated with a $\frac{1}{2}$ -in. transducer and a steel bar. The temperature coefficient of the core approximates that of the bed of the machine in order to compensate for expansion of the machine due to changes in ambient temperature or heat produced by the cutting operation. Under temperature controlled conditions, tests have been made which indicate that the transducer will repeat measurements to a few millionths of an inch with practically infinite resolution. Cuts involving a slide positioning tolerance of plus or minus 0.0002 in. normally require no temperature control.

A block diagram of the control system is given in Figure 8. The dial selector is a stepping switch that connects the various dials in sequence and lights an indicator lamp to show which dial is controlling the slide at any particular time. The

selected dial supplies a fine and a coarse signal to the slide position comparators and also controls the feed rate and rapid traverse. The fine signal is generated by a miniature coil-and-core arrangement that is identical to the construction of the feedback transducer. The coarse command signal is supplied by an inductive potentiometer behind the control dial that delivers a voltage analogous to the position desired. This voltage is compared with the output of a digital-to-analog converter that operates from the count stored in the position register.

A servomotor-driven flow-control valve establishes the desired feed rate. A voltage from the feed rate potentiometer on the operator's panel controls the operation of the servomotor and also is fed into an anticipating network to compensate for the velocity of slide movement. With the multiplicity of operating cycles and auxiliary functions characteristic of various machine tools, extremely flexible logic circuitry is required between the key reader output and the machine controls. The computer designed for this use is made up of AND, OR, and NOR circuits. Eight printed circuit boards are required to program the turret lathe.

The hydraulic system is of the "bang-bang" type. Because the feed rate is constant until the end of the cut and then is suddenly cut off, no change in finish or size is found as the end-point is approached. The slides are hydraulically braked and clamped once the desired end-point is reached.

4. Magnetic Scale Substitutes For Light Chopper

RAY BELL, Hughes Aircraft Co.

To its two-axis digital numerical system announced last year, Hughes Products has added a third-axis control that differs from the earlier approach in one significant way. It incorporates a magnetic scale for position determination instead of the photoelectric device used in the X and Y axes. As applied to a turret drill, the Z-axis control regulates four operations: depth of cut, rapid approach speed of the tool, a slower cutting speed, and a very slow creep feed as the tool nears the bottom of the hole.

The magnetic-scale method of position determination offers comparable accuracy but is less expensive than the incremental positioning device Hughes has been using in the X and Y axes. This incremental device consists of two photoelectric cells, two lamps, and a 100-slot chopper driven by the machine lead-screw. The chopper and the two photocells divide each rotation of the leadscrew into 200 parts. Thus if the screw pitch is 0.2 in., each pulse of light represents a movement of 0.001 in. A third photocell and light source and a disc with a carefully positioned hole supply the zero reference position for the control; the disc allows the cell to see the light only one point in the travel.

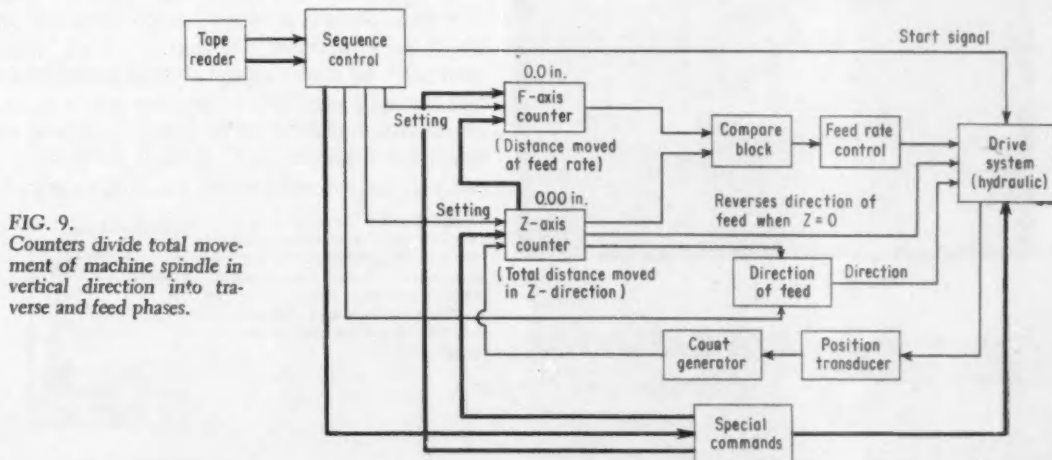
To make the magnetic scale transducer, lines 0.004 in. apart are etched on a metal bar 14 in. long, 3 in. wide, and $\frac{1}{2}$ in. high. A magnetic detector riding on the bar across the lines detects the presence or absence of an etched line. The permeability of the detector varies as the head moves, depending on whether the head covers an etched line or a solid portion of the bar so that an ac output is obtained. A shaping circuit converts this output into a square wave whose width is equivalent to movement of 0.002 in. To resolve measurement to 0.001 in., two such magnetic detectors are used, one trailing the other by 90 electrical deg. This arrangement not only solves the resolution problem but also provides a way to determine the direction of head movement.

Two other key components of the new control, Figure 9, are the Z-axis counter, which is preset with the total distance the tool must move from the zero reference point of the machine, and the F-axis counter, which is preset with the distance the tool must move at feed or cutting speed. The instructions for total movement are entered on the punched tape as four-digit binary coded decimal numbers. The Z-axis counter is in reality four separate decimal counters; inside each decimal counter are four transistorized binary flip-flops. The feed distance commands are two-digit numbers entering the F-axis counter, which consists of two decimal counters, each with four binary flip-flops.

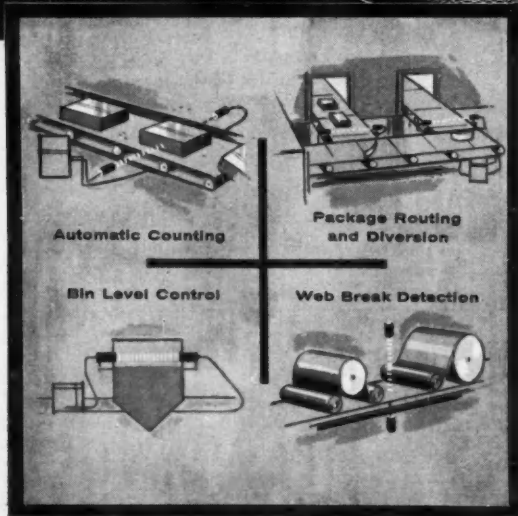
From punched tape instructions, the sequence control sets the F-axis and Z-axis counters, orders the direction of feed, and dispatches a start signal to the hydraulic drive system. As the tool starts its movement, the detector moves across the etched lines, and pulses are created to count down the Z-counter. Meanwhile both the Z-axis and the F-axis counter are being read and the outputs enter a comparison device. When the readings are exactly equal, a signal from the compare block orders the drive system to change approach speed to feed rate.

When the Z-axis counter reaches zero, a signal is sent to change the direction of feed. The choice of special commands includes: 1) dwell at the bottom of the hole to produce a good finish on a spot-faced hole and then rapid retract, 2) rapid retract with no dwell, or 3) retract at feed rate for a tapping operation.

If the command has been given for a retraction at feed rate, a special routine is followed (shown in the dashed lines on Figure 9). For this operation, the F-axis counter and the last two decimal counters of the Z-counter are joined to serve as a combination counter. The magnetic detector continues to generate pulses until the count is the same as when the feed rate originally took over; then the rapid approach speed is switched in to withdraw the tool.



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Automatic Welder Gets Position From Arc Current

KENNETH J. RHODES
A. O. Smith Corp.

Two new automatic arc welding machines are now in use at A. O. Smith to weld together the parts of right and left subassemblies for the frames of Chevrolet trucks. Each machine has four automatically controlled weld heads—two to make the 24-in. long welds between the inner and side rails at the front and two to make the 48-in. long welds between the same rails at the rear, see Figure 1. The four welds are made simultaneously, and the heads travel from the front and rear towards the center of the rails. Welding speed is 200 in. per min using a $\frac{5}{16}$ -in. diam welding wire at 550 in. per min.

The assembly to be welded is clamped into the machine as shown in Figure 2, and the four weld heads move along the seam on a fixed cam track having the contour of the work piece. The weld heads are 600-amp constant potential units designed and built by A. O. Smith. The arc is kept to the center of each seam by

a servoed hydraulic cylinder which positions each weld head, as can be seen in Figure 1. The electronic control system which positions the head is made by Control Laboratories, Inc.

The technique used for measuring the position of the arc relative to the seam is interesting and unique to this seam tracing equipment. The weld current itself, flowing from the arc to the two clamps which hold the pieces being welded, is the source of the position error signal. In this scheme two sets of fixed probes $2\frac{1}{2}$ in. apart contact the two rail sections along lines approximately equidistant from the weld seam. When the welding arc is centered on the seam, the currents in the two pieces being welded are equal and opposite, and the differential voltage drop from one set of probes to the other is zero. As the arc wanders off the center of the seam, a current imbalance results because the relatively high constant resistance of the seam appears more or less entirely in series with one of the current paths and not the other. Thus a differential voltage appears across the probes with a polarity that

depends upon the direction of the position error.

The magnitude of the position error signal thus derived is linearly proportional to the position error for small errors and tends to saturation for large errors. Signal magnitudes on the order of 10 mv are easily produced.

The remainder of the arc positioning control system is relatively straightforward. The dc error signal is amplified, then fed to a servo driver which produces power to operate the electromagnetic servo valve, which in turn causes the hydraulic cylinder to reposition the weld head to the center of the seam. The differential voltage amplifier is a vacuum tube type, but it uses a second-harmonic magnetic converter. Ac rejection at 60 cps is 100 db below dc gain to reduce control system sensitivity to stray pickup and ac ripple in the dc arc current. The servo driver is a transistorized feedback amplifier with constant dc gain and also incorporates ratio and slope controls that permit the maximum ac gain and the rate of gain reduction with frequency to be set easily.

FIG. 1. Welds on truck frame subassemblies are made by automatic weld heads positioned on the seam by electronic control system which notes difference in voltage drop due to arc current on either side of seam.

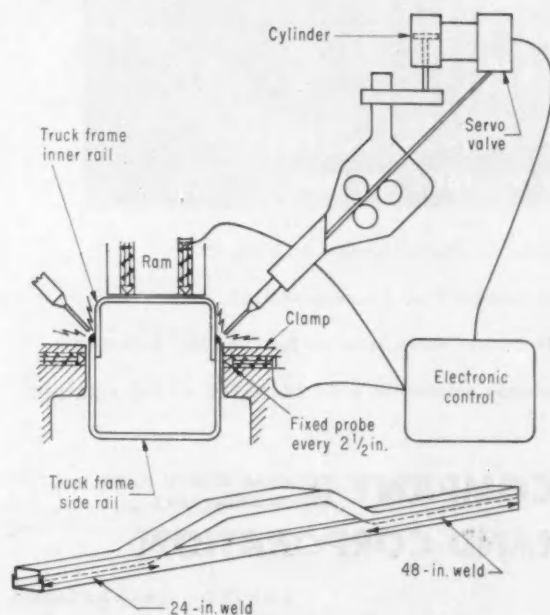
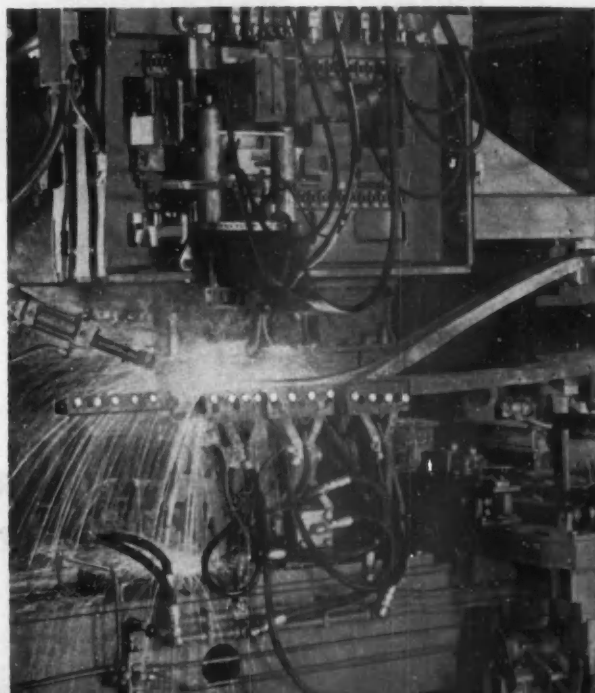
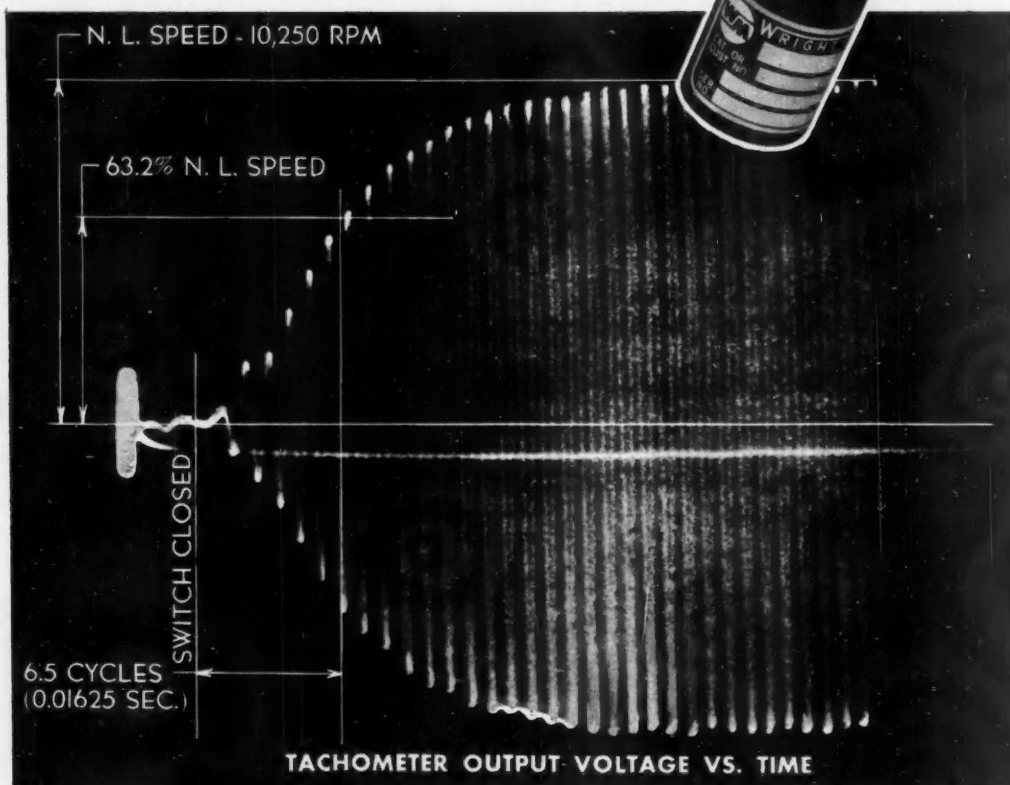


FIG. 2. Half of automatic welder making front weld on truck frame described in text. Arc position sensing probes are visible in front of and above truck frame just to right of arc.



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Recording a Variable and its Integral with One Pen

L. PRITKIN
Ridgefield Instrumentation Div.
Schlumberger Well Surveying Corp.

In the course of analyzing various materials by nuclear magnetic spectroscopy, Schlumberger engineers soon recognized the need for a simple method of integrating the NMR spectral records. The integral of the area under a recorded curve elicits significant information about the composition of the tested material. Many other records like missile thrust vs time curves, process stream flow rates, and gas chromatograms often need to be integrated, too.

Such continuous curves are most often plotted on a single pen strip chart recorder, one of the most precise and accurate instruments used for industrial testing. Taking advantage of the fact that a recorder is needed to plot the continuous curve, a simple integrating device, Figure 1, has been developed that not only computes the integral of the curve but records the integral with the same pen and on the same recorder chart once the integration has been completed.

Figure 2 shows the basics of the recording integrator. A linear-characteristic carbon-film potentiometer is mounted via a gear assembly, lower left of Figure 1, on the recorder motor shaft extension. A 20-vdc source from a Zener diode power supply energizes this transmitting potentiometer. Thus the voltage at the pot's

wiper arm is proportional to the instantaneous value of the recorded input function. The instantaneous voltage feeds into an operational amplifier with an RC integrating network. A spring-return switch, "Read-Integrate" in Figure 2, moved to the "Read" position connects the integrator output to the recorder when the operator—who watches the chart—judges that the original data has been completely recorded. A time delay relay causes the recorder to display the integrator value for a few seconds after which the integrator is automatically reset and the pen returns again

to recording the original data and computing the next integral.

A typical chart containing records of original continuous data and their integral values is shown in Figure 3. Here, the amplitude of the integral pulse indicates the area under the curve to the right of the pulse. A "Reset" switch on the cabinet panel permits the operator to discharge the integrating network at will, thus erasing defective data. A situation like this is shown in Figure 3.

The integrator-recorder combination provides a permanent, easy-to-read analog record of the integrated



FIG. 1. Prototype integrator and accessories.

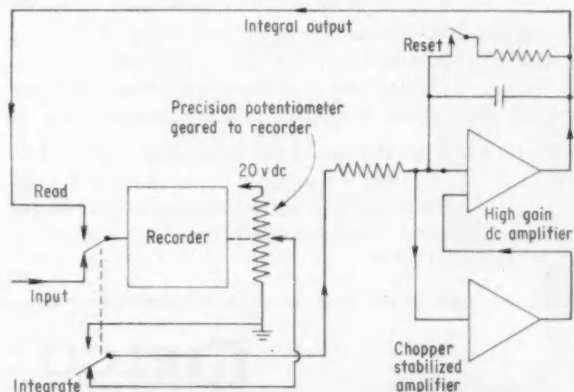


FIG. 2. Simplified hookup of integrator and recorder.

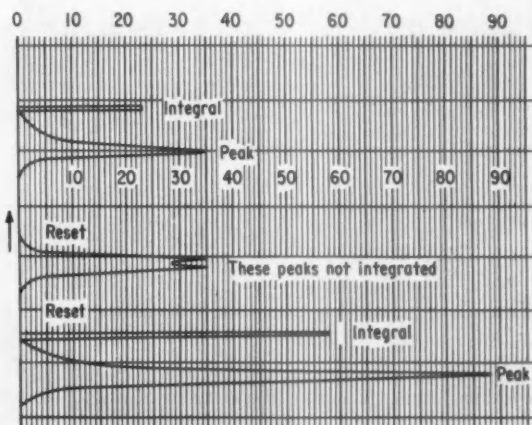
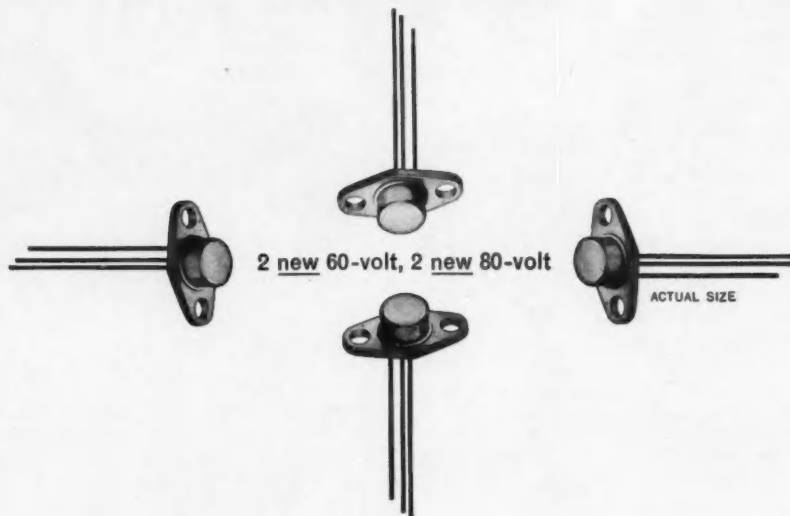


FIG. 3. Typical record of recorded functions and their integral values on the same chart.

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quantity. The shortest integrating time normally used is 6 sec to integrate full-scale sustained input to full-scale output. The readout resolution of the area under the curve is as good as the recorder accuracy of $\frac{1}{4}$ percent with integrating times as long as 4 min.

Since the integrator is basically an electronic device, certain desirable functions can be added easily. One, for instance, is the provision of an adjustable threshold. With this feature, the instrument starts integrating only when the input signal becomes larger than some minimum threshold value. Thus adjustable threshold eliminates the effect of noise and base-

line drift (as from a chromatograph) in the total integral. Adjustable threshold will introduce only a negligible error in the integrated value provided the maximum-signal to noise or maximum-signal to drift ratio is large.

Another possible accessory to the basic integrator is the addition of a long cable with a "Read-Integrate" switch at the end paralleling the "Read-Integrate" switch in the cabinet. When the recorder and the integrator are located some distance from each other, the operator can stand in front of the recorder, observe the record for the completion of the curve to be integrated, and

push the remote switch to "Read".

Larger integral values or increased resolution or both can be accomplished by adding an electrically operated odometer counter to the readout section. A set of contacts at the full scale position of the indicating meter on the cabinet, Figure 1, will index the counter one digit every time the analog value of the integral reaches full scale. Therefore, at the completion of a test, the total integral is the digital value shown on the counter plus the residual analog value indicated by amplitude of last pulse.

Schlumberger plans to market in the near future an integrator like the one described here.

Scale Models Save Computing of Cutting Lengths At Mill

L. N. BRAMLEY
British Iron and Steel
Research Association, London

Mental selection of the cutup lengths on a 200-ft steel section can lose upwards of 1.5 percent of the section length. Normal rolling mill practice requires the sawbench operator to select from his order list customer lengths that make the most economic use of the section. Computer selection can minimize this waste but requires an expensive, complex installation.

A simple \$300 scale model representing the section length and the customer order length in the form of half round plastic rods relies on the human aptitude of matching like objects. Result: a reduction of off-cut waste to 0.2 per cent. Programming time to select the cutting lengths on a 200-ft section length averages less than 20 sec and can be further cut by partial prefiling with commonly required standard lengths.

In the system each incoming order is simulated in the order department by scaling plastic rods to the required customer lengths. Customer identification is written on the flat surface of the rod and bundles of rods representing the orders to be cut by one shift are dispatched to the sawbench, where the rods are stacked in the Sectionmaster simulator on four racks with their marked faces up, see figure. Each rack is inclined slightly to the horizontal to butt the rods against the end of their rack. Ruled vertical lines represent 2-ft intervals.

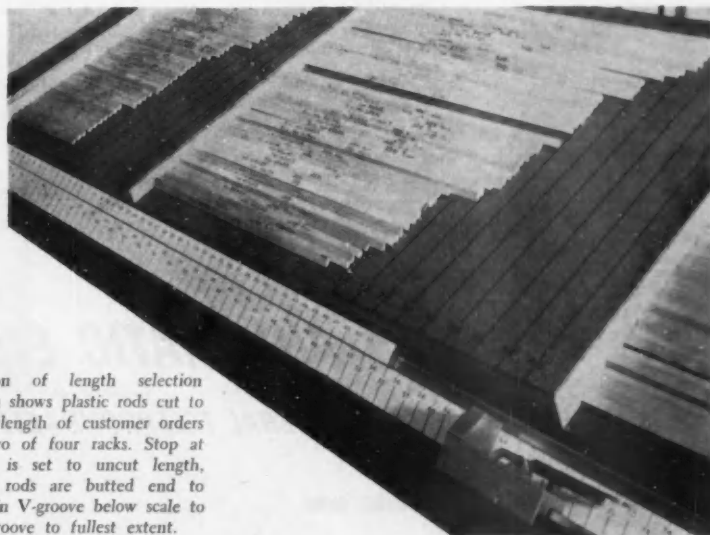
Below the racks is the scaled down

simulation of the measuring portion of the saw bench. A V-groove fixed to the side of the Sectionmaster at 45 deg to the horizontal represents the section length to be cut. One end is blocked off, the other being adjusted by a movable stop. A scale mounted alongside the groove marked out in 1-ft intervals up to 250 ft allows the operator to set the adjustable stop to the uncut section length.

When the operator receives the uncut section length information from the mill floor, he sets the stop and begins filling the groove with suitable rod lengths from the racks. His effective utilization of the available groove length is visible throughout the operation and allows him to improve his selection. A small subsidiary sliding

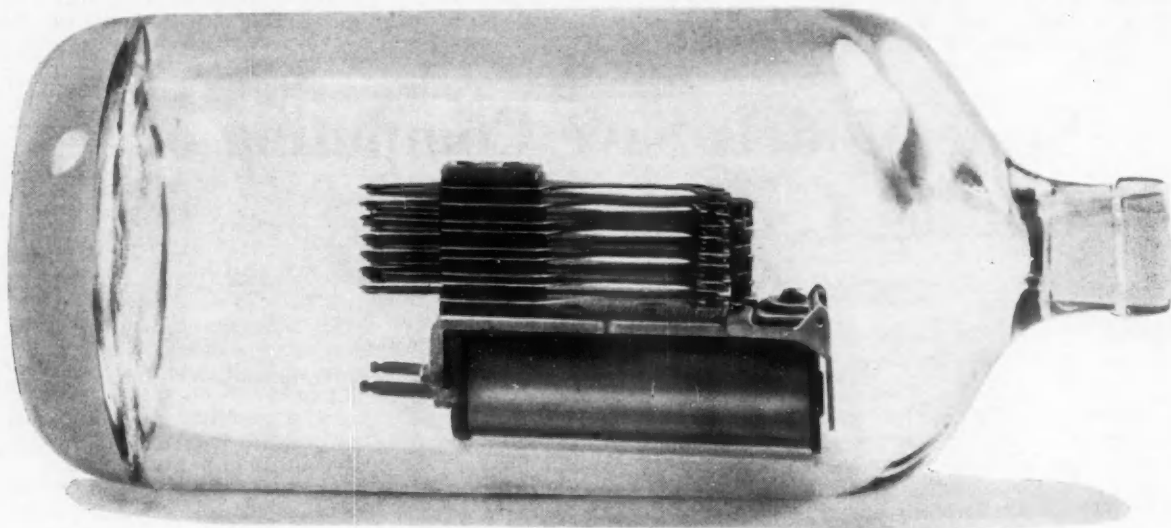
scale helps in filling the final 50 ft. When the groove is almost filled, the total length remaining is read off the main scale. If there is no rod to fill this remaining gap, the next shortest order is set on the sliding scale and the operation repeated until the best combination of orders is found.

Two future improvements on the scheme would reduce operator's selection time by about 10 percent. One is the provision of extra grooves which the operator can partially fill before he receives the final rolled length information. Automatic measurement of the section length on the runout table is the other, in which the length information drives a servo to set the adjustable stop in the groove automatically to the section length.



Portion of length selection bench shows plastic rods cut to scale length of customer orders in two of four racks. Stop at right is set to uncut length, scale rods are butted end to end in V-groove below scale to fill groove to fullest extent.

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Transparent Tape Programmer Breaks Sock Pattern Jacks

CHARLES CONWAY
Textile Machine Works

In the language of the knitting segment of the textile industry a "pattern jack" means a steel punching resembling a comb. As received by the sock manufacturer, this jack has a series of teeth along one edge as shown in Figure 1. Up to as many as 1,800 of these jacks are required for the production of a single pattern in the making of men's fancy patterned socks. The presence or absence of teeth in such a series of jacks constitute the pattern, as illustrated in Figures 2A and 2B.

The breaking-out of the required teeth by hand to produce a given pattern has always been a long, laborious task, requiring many hours of tedious painstaking labor to make certain that the proper teeth have been broken. To eliminate the human error in performing this job and to speed its production, Textile Machine Works engineers set out to produce a machine that would do the job accurately and quickly. The result was the jack breaking machine shown in Figure 3.

As its name implies, this is a machine that will automatically break the butts from a series of jacks in accordance with a pattern printed on a tape. This pattern is read by a photoelectric scanner (Figure 4) that sends impulses to solenoid operated cutter bars.

The pattern is first laid out on graph paper and then transferred to a transparent tape which is fed into the

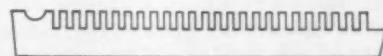
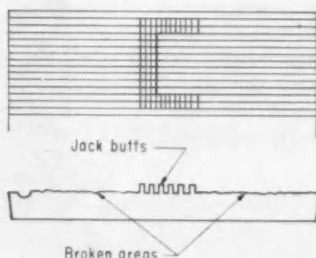


FIG. 1. "Jack" used for sock patterns is steel punching resembling comb.

FIG. 2. A—Butts or teeth are broken from jacks to leave desired pattern. B—Full pattern for single sock may take up to 1,800 jacks.

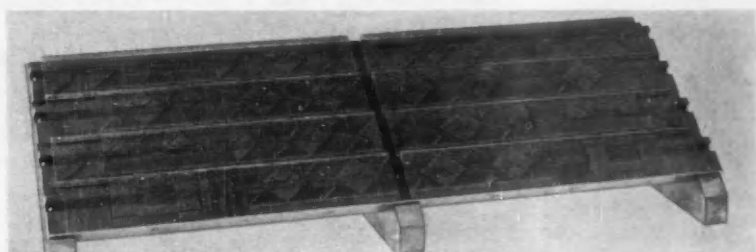


FIG. 4. Transparent tape is read by photoelectric scanner via commutation disk which connects proper solenoid to break the correct tooth.

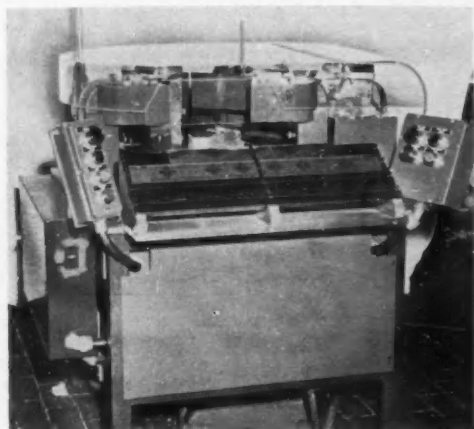
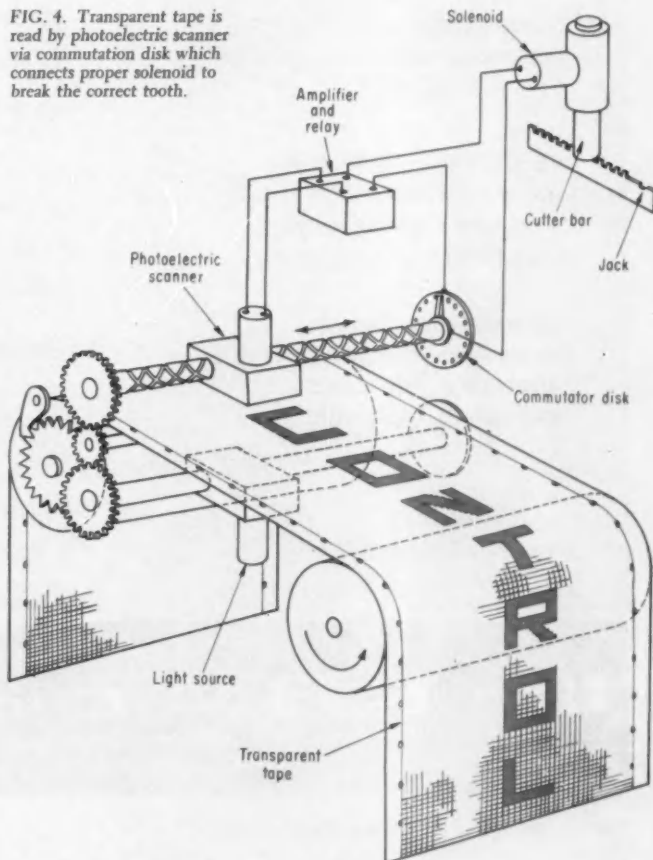
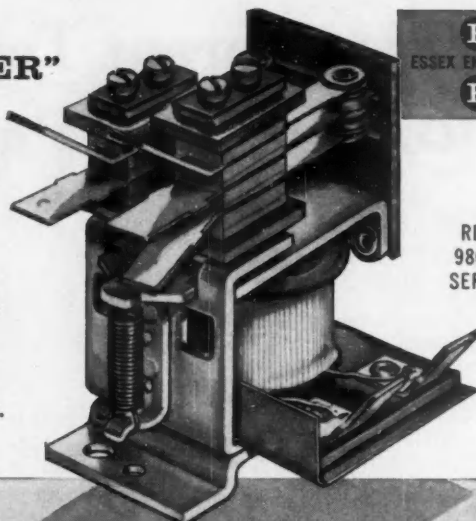


FIG. 3. Automatic jack breaker uses solenoid operated cutter bars to break jacks according to pattern on transparent tape.

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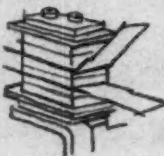
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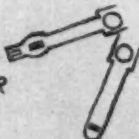
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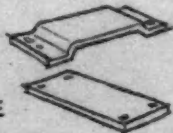
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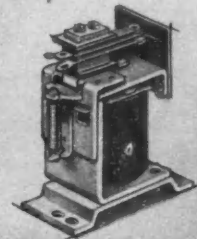


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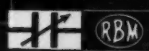


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scanner unit. After the jack blank is locked in the simple holding fixture, the cycle button is depressed and the photoelectric cell with lamp moves across the tape in line with one row of squares.

Each time the light beam is broken by a dark square on the tape, a corresponding solenoid is energized to release the spring-loaded cutter bar, allowing it to rise out of the path of its respective tooth on the jack. When there are no dark squares and the cell picks up a beam of light from the lamp

located underneath the tape, the solenoid remains deenergized. Thus the cutter bar remains in its down position, intercepting and breaking-out the butt as the jack is moved across its path. Completion of the cycle resets all cutter bars to their down position and racks the pattern tape one division in preparation for breaking the desired butts from the next jack.

This machine increases the number of jacks processed from the average of about 150 per hour by hand to approximately 450 per hour based on an

IDEAS AT WORK

efficiency figure of 80 percent. The photoelectric cell, amplifier, and relay make up the Model P22A controller with registry-type miniature light source and miniature photo pickup as supplied by the Tri-Tronics Co. All other design and manufacture of the machine was done by Textile Machine Works, a knitting machine builder.

Pinwheels Program British Movies

More than 200 out of Britain's 3,000 movie houses now use a pin-wheel type of programmer to control the presentations of complete shows, see Figure 1. The programming system is called Projectomatic and is built by G. B-Kalee Ltd. of the Rank Precision Industries Group to sell for \$1,200. The system not only switches over sound and picture automatically from one projector to another as each reel ends, having readied the following projector prior to changeover, but at the end of the feature brings on house and footlights, closes the screen curtains, and adjusts screen widths for the next film.

The programming sequence for the performance is stored on a 650-hole aluminum drum. The holes are arranged in 50 rows of 13 columns each, Figure 2. Pegs are inserted into the holes to determine the program, and protrude above the cylinder to actuate a miniature switch in each column.

With the film threaded in the projector—the only task left to the operator—an interval timer is set to

start the show at the correct time and the start button is pressed. The start button advances the drum to its first position where program pegs turn the footlights and houselights on, close the screen curtains, start up the record turntable, switch the sound to the turntable pickup, and adjust the screen masking for Cinemascope, wide screen, or normal width films.

At showtime the timer zeros, and its closing contacts fire the thyatron to advance the drum a further step. Now additional pegs on the drum coupled to the left-hand projector first strike the projector arc and start the film winding motor. As the film passes through the projector, the first of three self-adhesive silver foil markers on the edge of the film passes over a special pickoff mechanism. The foil short circuits two insulated portions of an idling pulley, and the pulse fires the thyatron to advance the drum to its next step. Here pegs initiate the opening of the tabs and operate the dowsner shutter solenoid to project the picture on the screen.

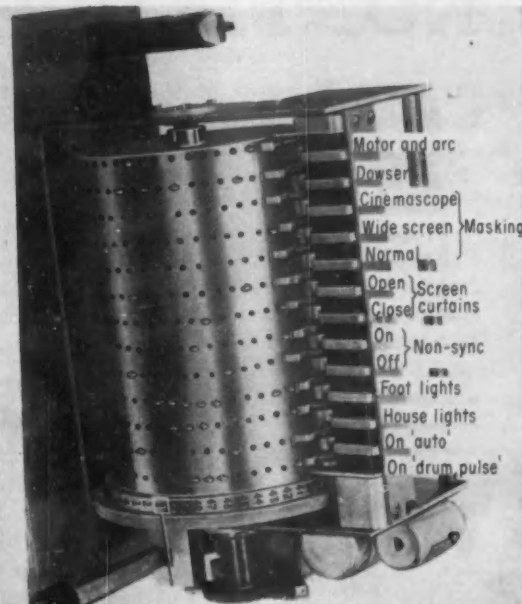
The second cueing marker is located 13 in. from the start of the optical sound track to advance the drum another step and switch the sound from the turntable pickup to the film track. A final cueing marker 9 ft from the title fadeout sequence on the film advances the drum to dim the footlights by energizing a thermistor controlled saturable reactor. The drum is then ready for automatic projector changeover.

As the first reel nears completion, three more cue strips starting 24 ft from the end of the reel initiate sequentially on the standby projector a warning buzzer, striking of the projector arc, film winding motor start-up, and then simultaneous sound and picture changeover. This automatic projector changeover continues without interruption until the last reel of the feature. Here cue markers at the end of the film advance the drum—now programmed in the reverse order from startup—to shut off the projectors and automatically close the completed movie show.

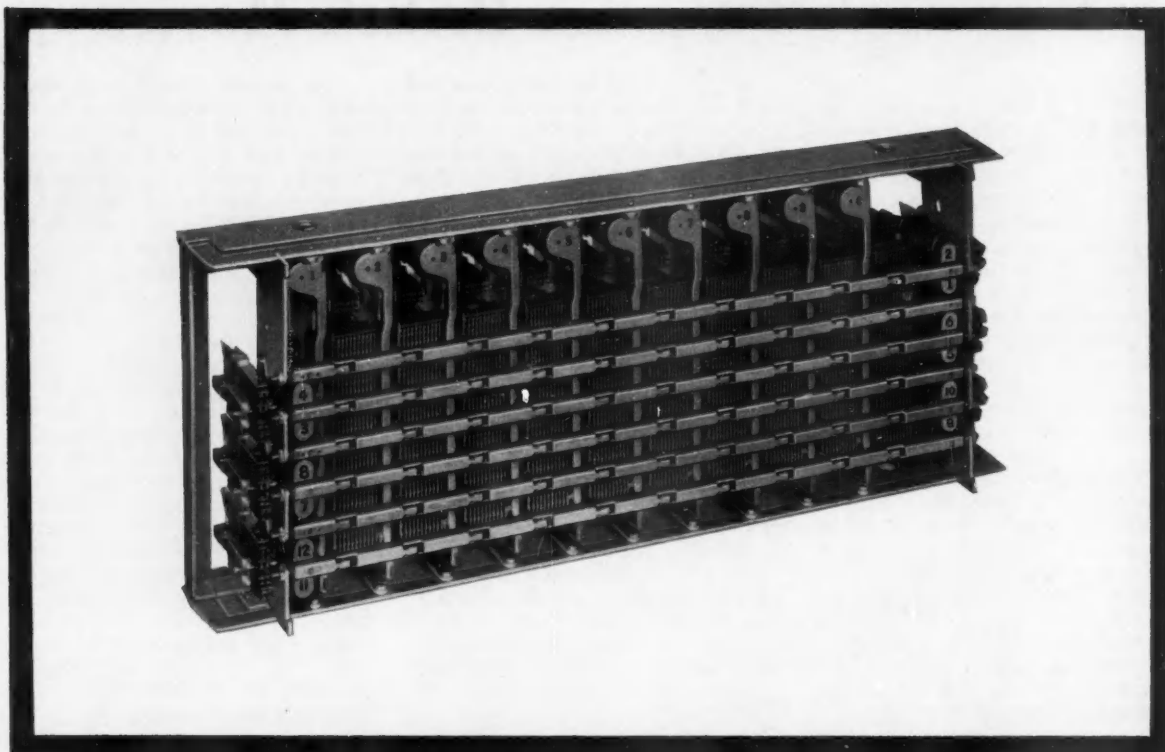
FIG. 1. The small box on the wall behind the movie projector contains an aluminum drum in which small pegs inserted manually trip miniature switches to control the presentation of an entire movie show.



FIG. 2. Close-up of drum shows 13 rows of 50 holes each and function of each channel. Drum moves to next step on pulses from projector or from pegs in right hand channel.



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POTENTIOMETRIC RECORDER

retransmits, uses strain gage transducer.

The miniature potentiometric recorder, shown at right, with torque motor pen drive and ac amplifier module, and its companion strain-gage differential pressure transmitter are the first items in a new line of electronic process control devices, featuring several useful design innovations. The recorder, for instance, not only develops an ac signal for driving each pen servo and other components like controllers but also retransmits a low noise dc signal proportional to the recorded variable for feeding data loggers and computers. The differential pressure transducer is completely passive; it uses an internally mounted four-wire bonded strain-gage bridge to develop a sufficiently strong dc signal, even at 0.5 in. of water, to drive the pen. Resistance bulb or thermocouple inputs can also be accepted.

Recorder

The miniature recorder is completely transistorized, a feature which allows encapsulation and modularization of certain functional portions of the recorder. This, in turn, permits the basic recorder design to be easily packaged for ac and dc, high and low level input signals and also permits rapid troubleshooting and repair.

With preamplifier modules installed, for example, the recorder input may be as small as 0 to 5 mv dc; for inputs of 0 to 1 vdc or greater, the preamp is not needed.

The input module, besides accepting differential inputs, also provides dc isolation, thereby eliminating noise pickup. Even after installation, coarse adjustment of zero or span can be conveniently made by simply looping wires through

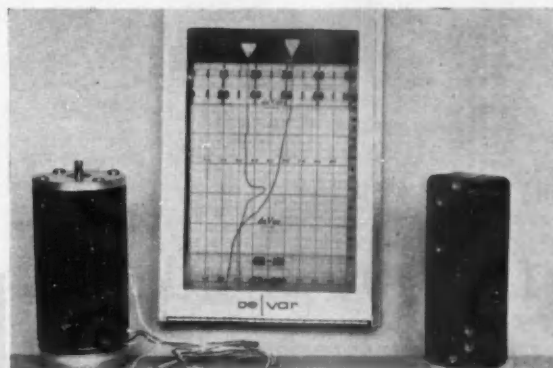
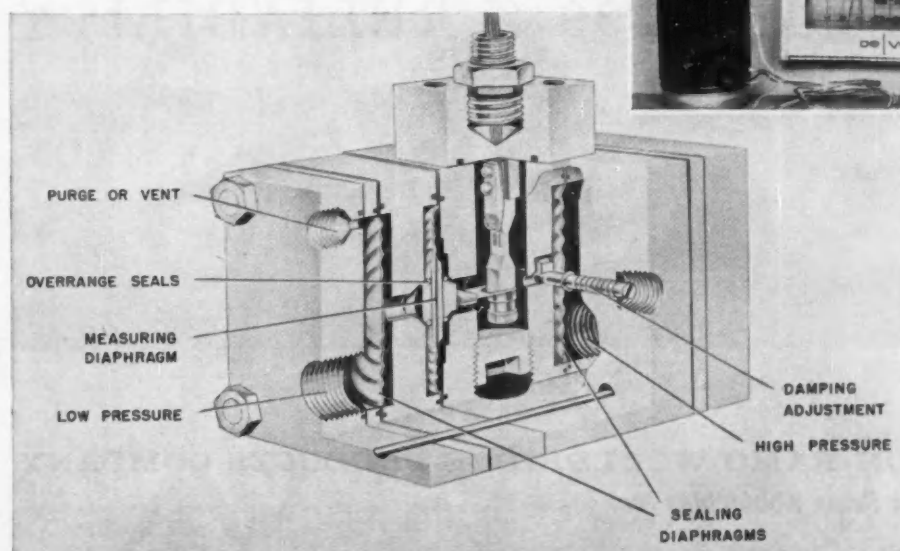
the secondary of the input transformer. Fine zero and span adjustments are also included.

Other features of the recorder are: 4-in. chart width, $\frac{1}{2}$ and 1 in. per hr standard chart speeds; 6 in. of visible chart; rectilinear chart markings; one, two, or three pens, each with different color ink; optional standby battery reserve; and torque motor pen drive that gives full-scale response in 1 sec with a frequency flat to 10 cps.

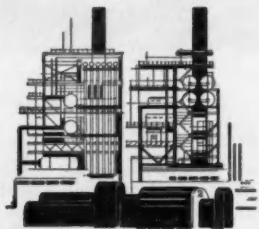
Differential pressure transducer

Differential pressure is applied to two stainless steel sealing diaphragms and is transmitted through two oil filled silicone chambers to the metallic measuring diaphragm. (See figure at left.) The diaphragm converts the differential into a force which deflects the bending beam and thereby causes the bonded strain-gage bridge to deliver a dc output bearing a linear relationship to the differential pressure. The transmitter exhibits excellent temperature stability, the manufacturer says, as well as being insensitive to vibration and acceleration.—deVar Systems, Inc., Glenbrook, Conn.

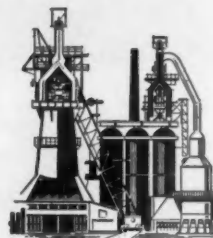
Circle No. 309 on reply card.



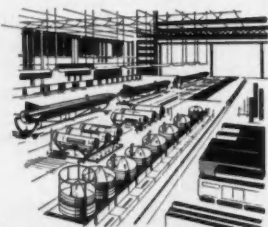
Above—Potentiometric recorder with pen drive (1) and amplifier module. At left—Differential pressure transducer.



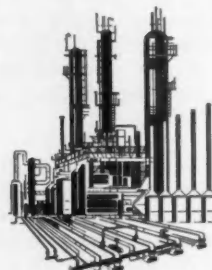
ELECTRIC POWER



STEELMAKING



AIRCRAFT AND MISSILES



OIL REFINING AND CHEMICALS

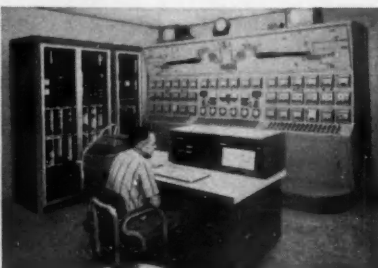


RW-300

173,000 HOURS...99+% RELIABILITY



Federal Aviation Agency, Atlantic City,
New Jersey—air traffic control simulation



Riverside Cement Company, Oro Grande,
California—cement manufacturing



Douglas Aircraft Company, Santa Monica,
California—missile component testing

THE THOMPSON-RAMO-WOOLDRIDGE PRODUCTS COMPANY

a division of **Thompson Ramo Wooldridge Inc.** 202 NORTH CANON DRIVE • BEVERLY HILLS, CALIFORNIA • BRADSHAW 2-8892

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THE RW-300 IS THE ONLY FIELD-PROVED DIGITAL CONTROL COMPUTER FOR INDUSTRY

The RW-300 has logged 173,000 hours of on-line operation—more than six times as many as logged by all other industrial digital control computers combined. The solid-state RW-300 computer is providing outstanding performance with better than 99% reliability in a diversity of around-the-clock applications.



In chemical plants and oil refineries, it is increasing yields and reducing costs. It is offering increased efficiency and safety for the operation of blast furnaces and the generation of electric power. It is bringing new techniques to the manufacture of cement, to the control of air traffic, and to the production-testing of aircraft, missile, and electronic components.

More important, the RW-300 is the only digital computer that has been trusted to "close the loop" in fully automatic industrial installations. That is why more and more companies are specifying the **experienced** systems engineering and **field-proved** equipment of The Thompson-Ramo-Wooldridge Products Company, the pioneer and leader in industrial computer control.

For further information on the RW-300 and the associated engineering services, call or write Mr. Raymond E. Jacobson, Director of Marketing.



B. F. Goodrich Chemical Company, Calvert City, Kentucky—chemical process control



CIRCLE 159 ON READER SERVICE CARD

NEW PRODUCTS

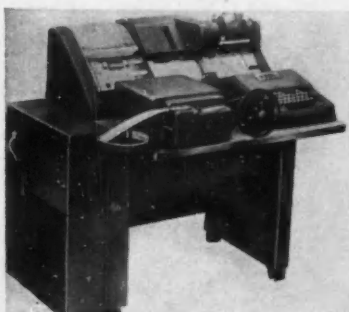
DATA HANDLING & DISPLAY



PORTABLE LAB UNIT

This portable magnetic tape recorder is a complete 7 or 14-channel recording and reproducing system for instrumentation or general laboratory use that is contained in a case only 1 x 2 x 3 ft. It can be used in its mobile case or can be rack mounted. Either $\frac{1}{4}$ or 1-in. wide tape on 10 $\frac{1}{2}$ -in. reels may be accommodated at six speeds from 1 $\frac{1}{2}$ to 60 ips. Cumulative flutter is below 0.6 percent peak to peak at 60 ips with tape speed deviations of no more than ± 0.25 percent and start time of 3 sec. Frequency response is dc to 200 kc (with -25 db signal to noise ratio). Power required is 28 vdc or 115 vac, 60 or 400 cps. Weights: 160 lb.—Ampex Data Products Co., Redwood City, Calif.

CIRCLE NO. 310 ON REPLY CARD



UNIVERSAL CONVERTER

Shown above installed on the table of an IBM card punch, the Model C750 punched tape to card converter is said to be the only machine capable of processing all punched tapes. Any 5, 6, 7, or 8-channel tape can be used as input for IBM 124 or 126 punches. The punches can still be used for man-

ual keypunching. A plug-in programmer allows for various applications. The tape reader, only 12 in. wide, 18 in. deep, and 8 in. high, is connected to a control module in an arrangement that allows easy access to the circuitry in the module.—Systematics, Div. of General Transistor Corp., Redondo Beach, Calif.

CIRCLE NO. 311 ON REPLY CARD

STURDY PERFORMER

A miniature tape recorder designed for use in missiles can operate through a 500-g impact deceleration and survive a 1,500-g shock without loss of data. Mounted in a hermetically sealed cylindrical case 3 in. high and 4 in. in diam, the package including tape weighs less than 4 lb. The unit will record 30 sec of analog data on 14 tracks of 1-in. tape. Crosstalk is approximately 40 db below signal level for staggered seven-track heads and 34 db for a single 14-track head. Wow and flutter are within 1 percent rms.—Recording Equipment Dept., Westrex Corp. Div. of Litton Industries, Hollywood, Calif.

CIRCLE NO. 312 ON REPLY CARD



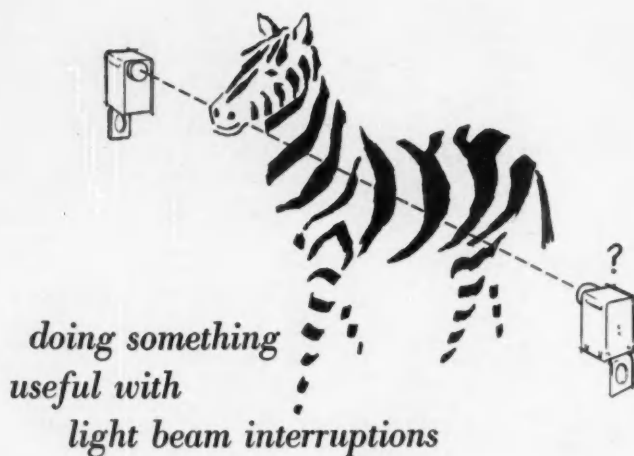
READS LOOPS AND STRIPS

Two flip-flops in the transistorized circuit of this bidirectional, high speed perforated tape reader control four solenoids which start and stop the mechanism. High speed search and reverse are provided in the loop or strip device. Silicon photodiodes sense perforations; self-cleaning action by the tape is a feature. Standard unit is complete with 8-level (plus sprocket) head, power supply, gating and shaping circuits, and amplifiers. Variable tape guide is adjustable to read 5, 6, 7, or 8-level tape. Device requires 7 in. in standard 19-in. rack.—Dykor Tape Reader Div., Digitronics Corp., Albertson, N. Y.

CIRCLE NO. 313 ON REPLY CARD

100 MILLION CAPACITY

A new disc file memory that uses multiple read-record heads to cover the surface of storage discs boasts nearly a 100 million character capacity, said to



Our affiliate, The Fisher-Pierce Co., is in the photoelectric control business and began fooling around with CdS photocells as a replacement for phototubes some 6 or 7 years ago. We in turn are pretty well into the electromagnetic relay business, and have been tweaking springs and whiffing magnets for about 20 years. It shouldn't surprise a soul then to learn that we have a new line of photorelays, consisting very simply of the respective products living inside a little can. This is a new "line", which gives you a choice in the type of cell, relay contact arrangement, packaging and operation under on-off, slowly changing or high ambient light conditions. The 8RCO1A, for example, has a CdS cell, responds to "light—no light" conditions, switches 3 amp. 120 VAC resistive loads with SPDT contacts, and has an aluminum dust cover with plug-in base. If your machinery or control circuit is already built, you might be more interested in the complete "package deal" consisting of both photorelay receiver and light source, whose application requires bolting the units onto something and plugging in the line cord.

There are all sorts of things these photorelays can do for you, coupled with a small amount of ingenuity and 120 volts. They can act as the brains to prevent a

process or machine from grinding on if the feed is empty or the operator's hands are in the way; look at the level in a bin or column, or "measure" the level between set points; turn on inside lights in response to a night watchman's flashlight; switch display or sign lighting on at dusk, off at midnight, on again from 6 A. M. to dawn, in conjunction with a time switch (this is the sort of thing in which Fisher-Pierce shines); and all the familiar counting, door-opening and 60-second hand-drying applications.

If you're interested in more exotic uses and have any hot nonincandescent bodies lying around, we can build you a special model with a cadmium selenide cell responsive to infrared rays (sources of infrared we cannot supply at the moment). Other non-standard possibilities include hermetically sealed units, special contact materials and units with low or high foot-candle turn-on points.

Be not faint of heart if your application lies beyond the commonplace. One man of vision found success and happiness by using a Sigma Photorelay in his Chinese fortune cookie machine... with a little luck, you might be able to open a new frontier in light-beam-actuated swiss cheese manufacture. Bulletin with guiding specs on request.



SIGMA

SIGMA INSTRUMENTS, INC.
69 Pearl Street, So. Braintree 85, Mass.

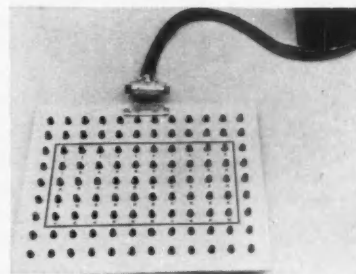
AN AFFILIATE OF THE FISHER-PIERCE CO. (Since 1939)

NEW PRODUCTS

be 10 times more than existing files. Access time is reduced from the 700 millisecond needed by present units to 150 millisecond. One model has a capacity of 617,642,752 bits, uses 64 discs and head positioners, each with two pairs of heads; a smaller version, with 16 discs and smaller capacity per surface, has a capacity of 154,409,124 bits. The larger machine measures 84 in. long, 60 in. high, and 32 in. deep, including cabinet. It weighs 3,000 lb and consumes 7 kw power. Cost is a fraction of other systems of comparable performance.—Telex, Inc., St Paul, Minn.

Circle No. 314 on reply card

RESEARCH, TEST, & DEVELOPMENT



FOR TESTING CABLES

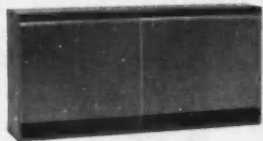
Testing of cable connected equipment is simplified by the use of the new Cable-Connek fixture now on the market. The flat 1/2-in. panels contain a cable receptacle connected to an array of junction points. Factory wiring allows ready reference between connector pins and the corresponding junctions. Any standard, miniature, or subminiature connector with up to 50 contacts may be specified. The test circuit can be connected directly on the panel; each junction point will accommodate at least two leads.—Price: \$20-35, depending on number of contacts—Plastic Associates, Laguna Beach, Calif.

Circle No. 315 on reply card

HAS NO POTS

The new V44 all-electronic digital voltmeter completely eliminates the need for periodic adjustment of trim

BENDIX G-20



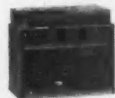
WITH ORGANIZATION CHART DESIGN



MEANS PRACTICAL EXPANDABILITY IN



BALANCE WITH APPLICATION GROWTH



Just as the organization chart of any enterprise provides the framework for dynamic growth and adaptation, so "organization chart" design provides the framework for unparalleled expandability in the Bendix G-20 data processing system. This means that your G-20 can economically match, step by step, your expanding scientific or business computational workloads ... without sacrificing system balance. • Key to the organization chart efficiency of the Bendix G-20 is the ability of the Central Processor to "delegate" routine data handling tasks to control buffers, acting as "line supervisors." Thus freed, the Central Processor can make most efficient use of its high computation speed, its ability to schedule program priorities and

direct accessory equipment assignments. • The ability to employ many control buffers gives new meaning to expandability in the Bendix G-20. Up to 70 input/output units can be directed by each of these "line supervisors." The Bendix G-20 has a complete line of accessory equipment including keyboard, paper tape, punched cards, high speed line printers, and 2 million word magnetic tape units. • Memory represents another dimension of G-20 expandability, ranging from 4,096 to 32,768 words. • Investigate the organization chart design of the Bendix G-20. See how it provides balanced, practical expandability ... at a cost that assures unequalled data processing performance per dollar invested. • *For detailed literature write:*

Bendix Computer Division
DEPT. W-27 LOS ANGELES 45, CALIF.



Engineering notes
from the **SM/I**
REPORTER

BY STANLEY M. INGERSOLL, Capabilities Engineer



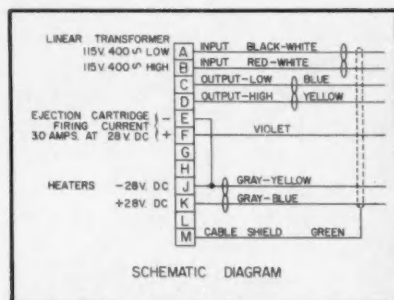
Report No. 12

TV 2020 Ejectable Vane Angle of Attack Transducer

Precision built for stringent missile applications, the self-powered TV 2020 provides an AC output proportional to the direction of air flow surrounding a vehicle. The ejectable vane, an optional feature, is affixed to the shaft by calibrated shear pins. It may be ejected by a minimal explosive charge contained within the vane and initiated by an electrical impulse. A heater within the metal of the vane itself makes it invulnerable to icing. The vane arm, shaft and counterweight structure of the TV 2020 are stainless steel and its stable case and structure are cast aluminum. Silicone oil of relatively low viscosity is used as the damping medium. The vane arm is interchangeable and will work with any transducer of the TV 2020 type.

Typical Performance Specifications

Angular Range	±15°
Electrical Input	115 volts at 400 cps
Electrical Output	0.3 volts rms 400 cps per degree
Total static error (max.)	Between +7.5° and -7.5° ±0.15° between +7.5° and +15° ±0.45° between -7.5° and -15° ±0.45°
Operating Mach Number Range	0.2 to 7.0
Operating Temperature Range	-54° to +125°C.
Heater:	
Power Requirements	250 watts
Operating Voltage	28 volts DC
Size:	
	4 3/4" diameter of mounting flange 4" deep
Total Weight	3 lbs., 5 oz.



For more information and complete operating specifications, write or wire SM/I today. Address your inquiry to Stanley M. Ingersoll, Capabilities Engineer.

SM/I

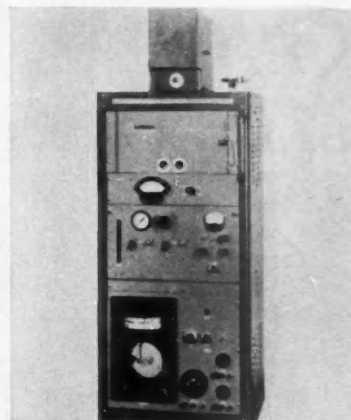
SERVOMECHANISMS/INC.

Los Angeles Division
12500 Aviation Boulevard
Hawthorne, California

NEW PRODUCTS

pots in decade circuits—there are none. The manufacturer states that the instrument is as stable and as accurate as electromechanical meters. Balancing time is only 5 millisecc, permitting high speed measurement of transient phenomena. Plug-in accessories allow measurement of either low level dc or ac voltages: one preamp permits a $\pm 99.99/99.9$ mv dc capability; another allows ac voltages of $9.999/99.9/999.9$ from 30 cps to 10 kcps to be measured. Unit is 10 1/2 in. high, 15 1/2 in. deep to fit 19-in. rack. Price: \$6,150.—Non-Linear Systems, Inc., Del Mar, Calif.

Circle No. 316 on reply card



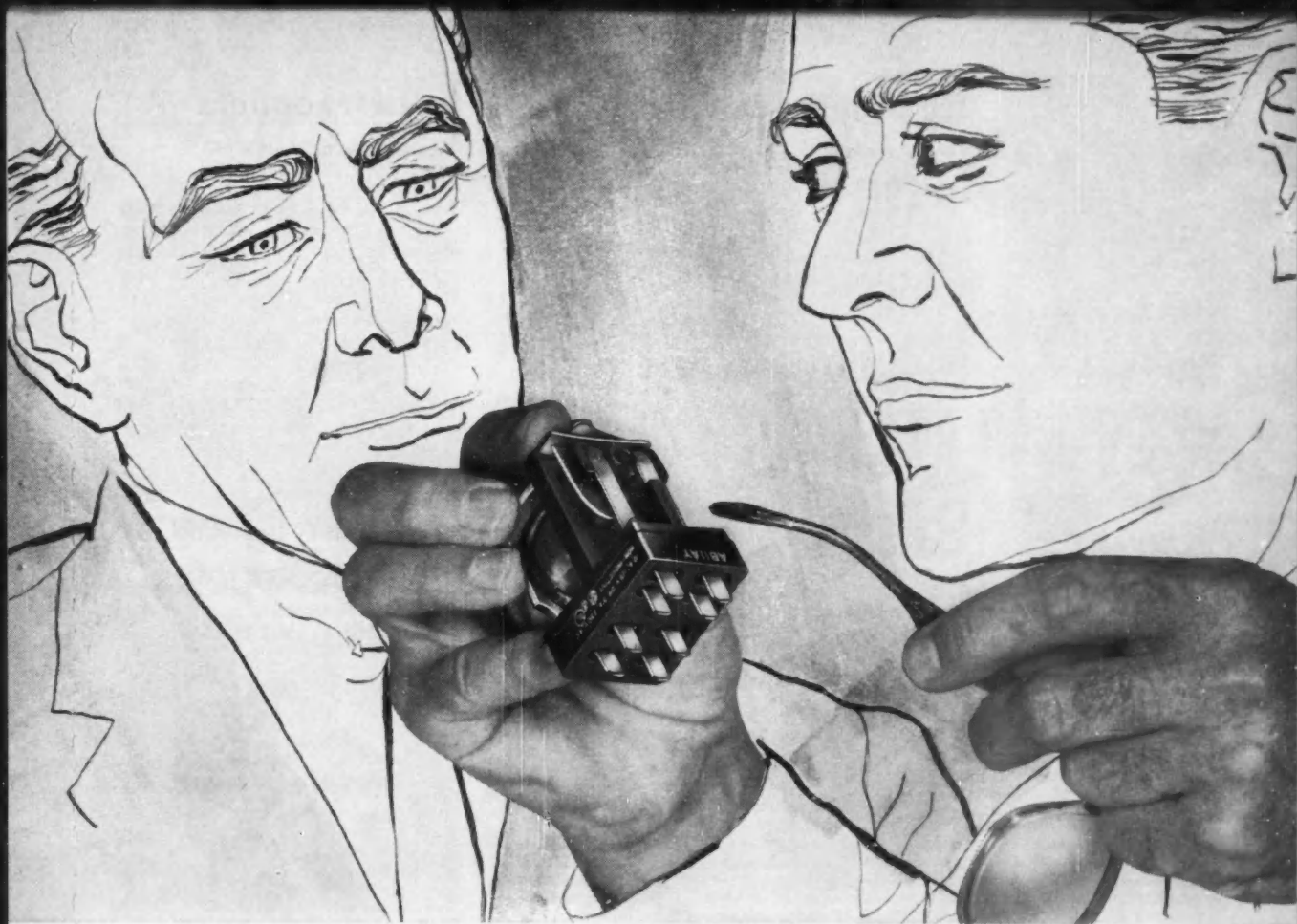
WIDE TEMPERATURE RANGE

A new programmed-temperature gas chromatograph features a wide temperature range. The Model 17 permits column operation from ambient to 500 deg C. Two identical symmetrically heated columns are used: one is for analysis, and the other discharges through the reference detector for column vapor pressure compensation. Temperature programming is by a cam controller which permits reproduction of the desired schedule—linear, exponential, or other type of profile. Price: \$5,197.—Loe Engineering Co., Pasadena, Calif.

Circle No. 317 on reply card

PLUS...

(318) A low noise, high gain, wide band lab amplifier that may also be used as a white noise source has been made available by Shapiro & Edwards Electronic Instruments, S. Pasadena, Calif. . . . (319) Monostat Corp.,



appearances are not deceiving

THIS P&B 10-AMP RELAY IS AS RELIABLE AS IT LOOKS

Our AB relay looks rugged . . . and it is. You can specify it for 10 amp switching and confidently expect 100,000 cycles. Yet it is compact, easily mounted, and does not require special handling. Installation is simple, using your preference of screw terminals (adapters), quick connects, or dip soldering.

Designers specify the AB for air conditioners and other products where dependable, continual service is paramount.

These standard AB and ABC relays are listed by Underwriters' Laboratories and Canadian Standards Association:

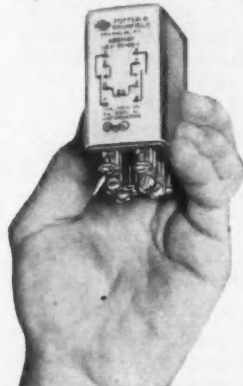
Type	Arrangements	Type	Arrangements
AB7AY	DPST-NO	ABC7AY	DPST-NO
ABBAY	DPST-NC	ABC8AY	DPST-NC
AB11AY	DPDT	ABC11AY	DPDT

Coil voltages: 6, 12, 24, 115 and 230 volts AC, 50/60 cycle.
Contact rating: 10 amps, 115 volts AC or 5 amps, 230 volts AC noninductive.

U/L File E-29244

CSA No. 15734

Write for complete data or contact your nearest P&B sales engineer.



ABC Series—AB series can be supplied enclosed in sturdy metal dust cover, $1\frac{3}{16}$ " x $2\frac{5}{16}$ " x $2\frac{3}{16}$ ".

AB AND ABC RELAYS ENGINEERING DATA

GENERAL:
Insulation Resistance: 100 megohms minimum.
Life: 3 million cycles (mechanical).
Breakdown Voltage: 1500 volts rms between all elements and ground.

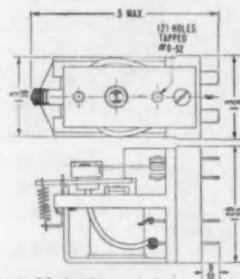
Temperature Range: DC: -55 to +45°C.
AC: -55 to +45°C.

Weight: AB—5 ozs. ABC—7 ozs.
Terminals: Fit $\frac{1}{4}$ " quick-connect terminals, or may be applied to printed circuits using dip soldering. Screw adapters furnished on request.

Enclosure: ABC: Heavy duty dust cover.
Dimensions: $1\frac{3}{16}$ " x $2\frac{5}{16}$ " x $2\frac{3}{16}$ ".

CONTACTS:
Arrangements: DPDT
Material: $\frac{1}{4}$ " dia. silver. Other materials available.
Load: 5 amps at 230 volts AC or 10 amps at 115 volts AC noninductive.
10 amps at 28 volts DC.

COIL:
Voltage: DC: 6 to 110 volts.
AC: 6 to 230 volts.



Power: DC: 2 watts nominal.
AC: 6.4 volt-amps.
Resistance: 35,000 ohms max.
Duty: Continuous: DC coils will withstand 6 watts at +25°C.

MOUNTINGS:
AB: Two 8-32 tapped holes on $1\frac{1}{4}$ " centers.
ABC: One 8-32 stud $\frac{1}{4}$ " long and locating tab.

P & B STANDARD RELAYS
ARE AVAILABLE AT YOUR LOCAL
ELECTRONIC PARTS DISTRIBUTOR



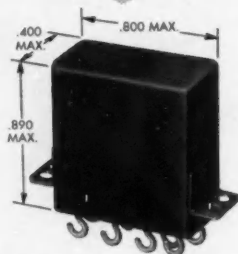
POTTER & BRUMFIELD

DIVISION OF AMERICAN MACHINE & FOUNDRY COMPANY, PRINCETON, INDIANA

IN CANADA: POTTER & BRUMFIELD CANADA LTD., GUELPH, ONTARIO

CIRCLE 163 ON READER SERVICE CARD

ALLIED CONTROL'S NEW Polarized Magnetic LATCHING Relay



Allied Type JP Relay
Weight: 0.6 ounces
Actual Size

The inherent vibration and shock resistance and high sensitivity of Allied's Type JP **Permanent Magnet** Polarized Latching Relay, combined with its ability to operate from a short pulse and remain operated without holding power, make it suitable for all phases of Aerospace applications.

Because of its latching feature and availability with single or double coils, it is also suitable as a logic or memory switching element in computers and data processing applications.

OPERATING CONDITIONS:

Vibration: 5 to 55 cps at 0.195 inch double amplitude • 55 to 2000 cps at a constant 30g

Shock: 100g operational

Sensitivity: JP (single coil) 115 milliwatt maximum transfer power • JPA-JPB (double coil) 230 milliwatt maximum transfer power

Contact Rating: Non-inductive—2 amperes at 29 volts d-c or 1 ampere at 115 volts a-c
Low level contacts are available on request

ALLIED CONTROL
ALLIED CONTROL COMPANY, INC.
2 EAST END AVENUE, NEW YORK 21, N. Y.

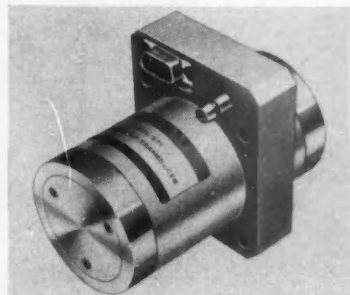
AL 200

NEW PRODUCTS

New York, N. Y. has recently developed a **microtitrator** which operates electrometrically using Beckman Microelectrodes. . . . (320) A portable 4-in. **oscilloscope** from The Scopes Co., Inc., Monsey, N. Y., operates at 3.7 kv, has bandwidth of dc to 6 Mc up to 100 mv/cm.

Circle No. 318, 319
or 320 on reply card

PRIMARY ELEMENTS & TRANSDUCERS



FOR ALTITUDE CONTROL

A new instrument system, the Model 571 altitude control transducer, uses a unique trapped air pressure design to provide an accurate altitude error signal. The device is referenced to the particular altitude to be maintained, and any change results in an error signal that can be fed into a flight control system. Operating range is to 80,000 ft, dynamic error band is ± 2 percent, sensitivity and threshold are 0.2 percent, response is 50 millise, and life expectancy is over 1,000 hrs. The device measures 2½ in. in diam by 4½ in. Price is expected to be low enough for use of the transducer in expendable drones, etc.—Bourns, Inc., Riverside, Calif.

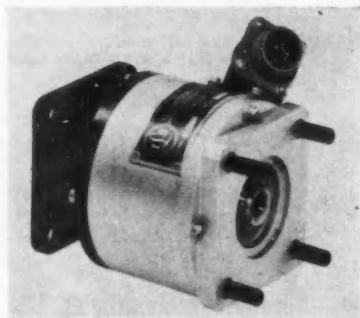
Circle No. 321 on reply card

NEW SYNCHRO LINE

Now ready for delivery is a complete line of Size 11 synchros designed to meet or surpass MIL-S-20708. A special potting compound makes possible operating stability over the entire temperature range of -55 to +85 deg F. Same characteristics in units designed for +200 deg F are also available. Accuracy of the devices is

within 3 sec. of arc.—Ketty Dept., Norden Div., United Aircraft Corp., Commack, N. Y.

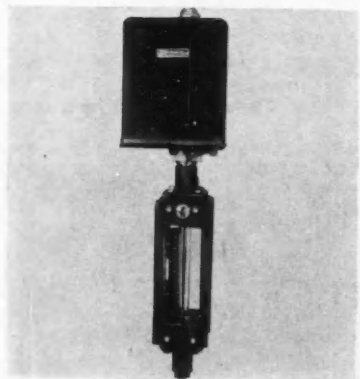
Circle No. 322 on reply card



MEASURES WIDE RANGE

A new magnetic pickup permitting accurate measurement of a wide range of engine and motor rpm is designed for sandwich mounting between a tach generator and a mounting pad. The pickup can deliver high level signals to operate counters or other instruments located up to 500 ft away. Speeds up to 10,000 rpm are possible; standard operating frequencies are 60 or 120 pulses per rev. Special assemblies allow operation at from 1 to 20 cycles per rev.—ILS Electronic Div., Meriam Instrument Co., Cleveland, Ohio.

Circle No. 323 on reply card



SOUNDS THE ALARM

A new line of rotameters is designed to measure fluid rate of flow and also to indicate abnormal high or low flows. The devices can be set to activate alarm devices and will start or stop motors, pumps, or control units. Typical unit shown above consists of standard 5-in. scale glass tube or metal tube rotameter and a sensing system mounted above the rotameter. Unit contains a magnet and a hermetically sealed reed-type alarm switch. Alarm switches for high and/or low

OCTOBER 1960

hays

RAMBLINGS ON INSTRUMENTATION



Reflections on a Second Soviet Sojourn

Editors note: Attendance at the recent International Federation of Automatic Control Congress in Moscow provided Mr. Sprague with an opportunity to continue his practice of picking the brains of intelligent U. S. Engineers overseas—just as he did some two years ago on another Russian junket . . . Herewith, his latest flights of fancy.

Department of Unsupported Generalizations

1. Russian automatic control engineers are more theoretically oriented than their U. S. Counterparts. However, they are concerned with the same theoretical problems that we are and—to the degree one could determine in a short visit—are not ahead or behind us.
2. The United States still is considerably ahead in the application of instruments and controls (we've got more of a greater variety of devices in daily use) but Soviet engineers have become more application-minded in the last two years.
3. A decision has been made at the highest level of the Russian government to go "all out" on automation. One gets the impression that whatever the Soviet control experts want in money, facilities, and people will be forthcoming and that, when this "wherewithal" is added to the talent and dedication possessed by their engineers and scientists, we can expect substantial progress on their part.
4. More automatic control "decentralization" is being practiced by the Soviets than two years ago. In 1958 one got the impression that "thinking will be done in Moscow; the best ideas worked out in Moscow will be practiced in the hinterlands". In 1960 one got the impression that "it's o.k. for people to think, to get automatic control ideas and to apply them whether they are in Moscow or not or whether they agree with Moscow or not".

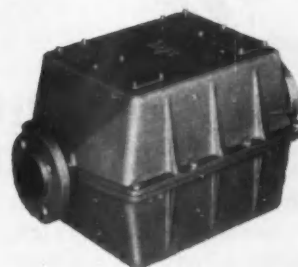
Department of Unanswered Questions

How does a free society match the concerted effort of a centralized society in a particular field (specifically automatic control)? If it decides it must match or exceed that effort, how does it "keep score", i.e. know whether it's ahead or behind? How, for that matter, does it profile on a continuing basis the quality and quantity of its own effort? Through technical conferences, exhibits, maga-

zines, etc? If so, shouldn't the role of technical societies be enlarged in the future to include a "report to the people" of the U. S. on our position in an important technical field? And, if we concluded that we were behind the Russians in automatic control, what should we do about it? Seek federal aid for universities working in automatic control? Give special tax write-offs for R & D work done by instrument companies? Set up a "Cabinet Minister For Automation"? And wouldn't this be simply adopting Russian methods to solve the problem? Help! Help!

Rifle Shot

We believe that we have developed the most accurate, most stable ONE INCH Electromagnetic Flowmeter in the market. We do not have two inch, four inch, six inch, eight inch, or eighty-four inch meters at the moment—though we hope to have them in the near future—so please do not write us for information on these sizes. But, if you are interested in a ONE INCH obstructionless electromagnetic flowmeter with these features:



- Independent of liquid viscosity, temperature turbulence, and density.
- Continuous range adjustment possible between 10 and 100% of transmitter calibrated flow—three position selector (10, 50, 100%) also available.
- 1/2% system accuracy.
- Conductivities handled to as low as 0.05 micromhos per cm².
- Common mode noise rejection—better than 3000:1.
- Adjustable system damping.

We would like to hear from you. Who knows—we might be able to help each other.

Phil A. Sprague

President

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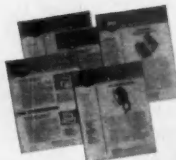
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NEW PRODUCTS

flows can be set.—Schutte and Koerting Co., Instrument Div., Cornwells Heights, Pa.

Circle No. 324 on reply card

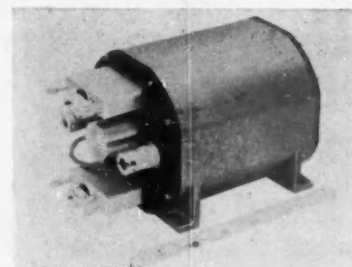
CONTROLLERS, SWITCHES & RELAYS



NONCONTACT GAGING

The delta unit controller shown above is designed to indicate and control measured quantities within prescribed tolerance. It handles both static and dynamic micrometric or macrometric measurements. A 25-ft cable is used for process control work and a 42-in. cable for applications in laboratories. The relay system—of the resistance-capacitance type—puts out 10 amps for servo or motor control at a high sampling rate. A line of probes and other accessories is available. Case measures 15 x 8 x 6 1/4 in. — Decker Corp., Bala-Cynwyd, Pa.

Circle No. 325 on reply card

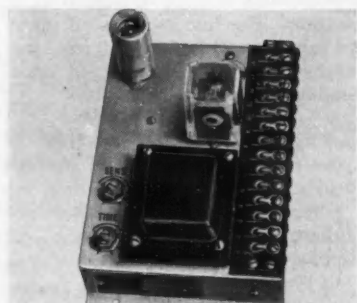


MAGNETICALLY ACTUATED

This new sampling switch uses magnetic actuation to eliminate sliding contacts, making possible a switch capable of fast operation at low signal levels and with a life exceeding 200 million operations. It is suitable for rapid sampling of low level transducers like strain gages and thermocouples. In many applications the switch introduces less than 10 microvolts of extraneous signal. Dwell

period may be as brief as 300 micro-sec; dynamic resistance is less than 1 ohm. A single unit can be used to commute as many as 90 double ended channels at rates to 3,000 total samples per sec.—Magnavox Research Laboratories, Torrance, Calif.

Circle No. 326 on reply card



DELAY'S ADJUSTABLE

Adjustment of the time response of this photoelectric scanner relay permits the light beam to be interrupted repeatedly for intervals shorter than the selected delay time. The delay can be from 50 millisecc up to $1\frac{1}{2}$ sec. Light source and photocell combinations permit choice of scanning distance and use of direct light or the manufacturer's proximity sensor. Current handling capability of the dpdt relay is 8 amps noninductive load at 115 vac. Power supplied can be from any 100-130 vac line.—Farmer Electric Products Co., Inc., Newton Lower Falls, Mass.

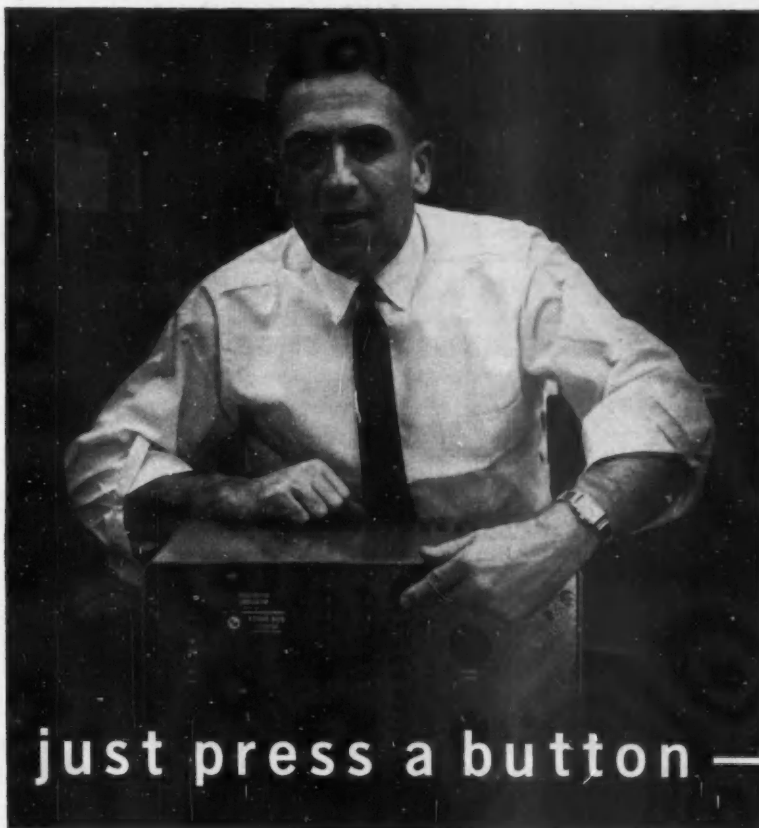
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POWER SUPPLIES



PERFORMANCE GUARANTEED

Offering improved circuitry and design that reduces required components by 25 percent, a new line of transistorized dc power supplies—one of which is



on this oscillator and you cover a
frequency range from 0.001 cps to 100 kc!

Here's a combination of wide frequency range (0.001 to 100,000 cps), low distortion (less than 0.1%), and high stability (less than 0.05% drift per hour) — in one highly convenient oscillator. The Model 440-A also provides both sine and square waves *simultaneously* over this entire frequency range.

Three banks of push-button switches give positive control of frequency with ease, and reset accuracy of better than 0.01%. The frequency multiplier switch covers the entire range in six decade steps. A vernier control varies the frequency continuously by an amount equal to the increment between adjacent third-bank buttons. This time-saving push button feature insures freedom from error, and enables use of untrained personnel for routine checking.

The 440-A's wide range offers more measurement flexibility. Its constant signal-to-noise ratio allows effective use of small signals in low level applications. Its low distortion eliminates troublesome harmonics in precise measurements.

Other Krohn-Hite oscillators include log dial-tuning Models 400-A (0.009-1,100 cps); 420-A (0.35-52,000 cps); 430-AB (4.6-520,000 cps) and others. Write for full information on Krohn-Hite Oscillators, as well as Krohn-Hite Amplifiers, Filters and Power Supplies.



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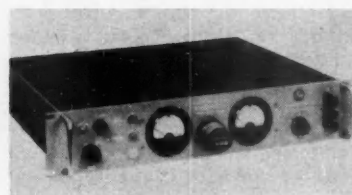
shown in use, p. 167—is designed for laboratory, test, and original equipment applications. The units are self-protecting and self-resetting and offer convection cooling. Performance is guaranteed to meet all printed specifications. The line includes 30 standard supplies with output voltages ranging from 1.5 to 100 volts and prices ranging from \$350 to \$1,100.

Characteristics:

Line regulation: within less than 10 mv for ± 10 percent line changes
Load regulation: within less than 0.1 percent from 0 to 100 percent load change
Ripple: less than 0.02 percent peak to peak or 20 mv rms
Drift: less than 0.1 percent in 24 hrs after 4-hr warmup

—Low Voltage Switchgear, General Electric Co., Philadelphia, Pa.

Circle No. 328 on reply card



ULTRA-REGULATED

This new transistorized dc power supply provides line and load regulation within 0.0005 percent at terminals and even regulates within 0.001 percent at 100-ft remote locations. Line voltage stability is within 0.0002 percent ± 10 microvolts for a 10 percent line voltage change. Other specifications: internal impedance, less than 250 microhms; hum and noise, 50 microvolts rms; output voltage drift, ± 0.01 percent; ripple, less than 250 microvolts rms. Output voltage is continuously variable from 0 to 36 volts; four models are available with maximum current ratings of 1, 3, 5, or 10 amps.—Krohn-Hite Corp., Cambridge, Mass.

Circle No. 329 on reply card

MISSILE BATTERY

High energy to weight ratio is the feature of a new silver-zinc secondary battery cell designed for use in airborne and missile electronics systems. The SC-04 weighs only 0.05 lb and takes up 1 cu in. including terminals and vent plug but has a nominal

(Continued on p. 177)

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6	20	34	48	62	76	90	104	118	132	146	160	174	188	202	216	230	244	258	272	286	300
7	21	35	49	63	77	91	105	119	133	147	161	175	189	203	217	231	245	259	273	287	301
8	22	36	50	64	78	92	106	120	134	148	162	176	190	204	218	232	246	260	274	288	302
9	23	37	51	65	79	93	107	121	135	149	163	177	191	205	219	233	247	261	275	289	303
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11	25	39	53	67	81	95	109	123	137	151	165	179	193	207	221	235	249	263	277	291	305
12	26	40	54	68	82	96	110	124	138	152	166	180	194	208	222	236	250	264	278	292	306
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309	320	331	342	353	364	375	386	397	408	419	430	441	452	463	474	485	496	507
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313	324	335	346	357	368	379	390	401	412	423	434	445	456	467	478	489	500	511
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315	326	337	348	359	370	381	392	403	414	425	436	447	458	469	480	491	502	513
316	327	338	349	360	371	382	393	404	415	426	437	448	459	470	481	492	503	514
317	328	339	350	361	372	383	394	405	416	427	438	449	460	471	482	493	504	515
318	329	340	351	352	373	384	395	406	417	428	439	450	461	472	483	494	505	516
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- 477—Basic Data on Process Control Systems, 50 cents
- 476—Three Ways to Simulate Dead Time, 15 cents

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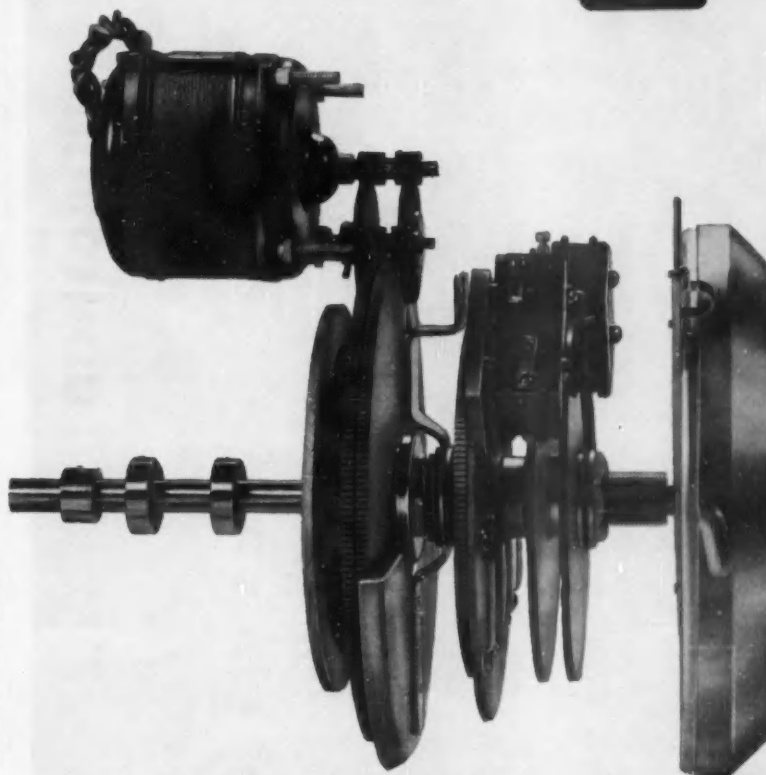
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CONTROL BITS

Ukrainian engineers have designed an automatic monitoring system that will enable a dispatcher to control the operation of a natural gas pipeline 1,800 miles long, according to TASS, the Soviet news agency. Transistorized instruments take measurements and transmit gas pressure and flow and compressor data to the central control center.

An analog data editing system that can receive and edit data at the rate of 15,000 characters per sec has been designed by IBM Corp.'s Advanced Development Div. Delivered last month to Tinker AFB, it will be part of a system to analyze loads imposed on aircraft.

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Behind Speedomax® G performance: STURDY MECHANICAL CONSTRUCTION

Why do Speedomax G users so often mention its excellent reproducibility . . . reliable accuracy . . . uninterrupted operation?

One of the reasons is the instrument's sturdy mechanical construction. The direct-drive measuring shaft keeps the split drive-gear, measuring slidewire contacts and any signalling, control, and/or retransmission contacts in rigid alignment. There's no backlash, no dead space. The result: accurate records, precise control.

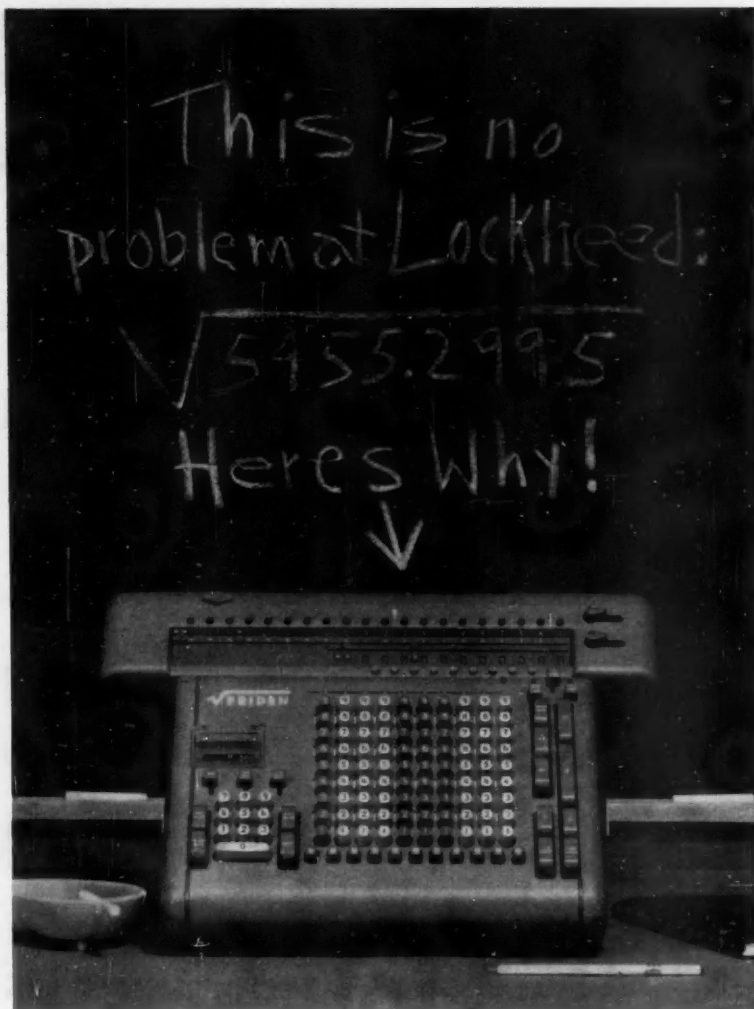
Additional mechanical features include: pointers and scales that pro-

vide excellent setability and readability . . . die-cast case, door, main frame and chart table . . . machine-cut gears and ball bearings. All contribute to the instrument's "staying power" under adverse conditions.

Such ruggedness is particularly vital in heavy industries where Speedomax G control systems are measuring and regulating temperature, pH, speed, mechanical and electrical load, and other quantities. For information on Speedomax G, or on any of our products and services, call your nearest L&N office or write 4918 Stenton Avenue, Philadelphia 44, Pa.

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At Lockheed's Sunnyvale, California Missile and Space Division, the Friden Square Root Calculator has been utilized since the Division began in 1954. To date, this installation has purchased more than 40 SRW's. Although the actual saving in dollars and cents could only be guessed at, Lockheed's continuing re-orders attest to the usefulness of the Friden SRW.

For a no-obligation demonstration of the Friden Square Root Calculator, contact your local Friden Man, or write: Friden, Inc., San Leandro, California.

THIS IS PRACTIMATION: *the practical application of automation principles to the creation and processing of source data.*

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BULLETINS AND CATALOGS

(400) NEW RECTIFIER LINES. General Electric Co. Specification Sheets ECG-481 and ECG-513, 4 pp. each. Provide full details on two new series of silicon controlled rectifiers: a C11 low-current series and a C40 medium-current series. Illustrations include characteristic curves, circuit diagrams, and dimension drawings.

(401) CORROSION PROOF CONDULETS. Crouse-Hinds Co. Bulletin 2699 revised, 20 pp. Up-dated version of this bulletin features six pages of tables listing a wide variety of corrosive substances along with the appropriate corrosion-resistant metals and finishes used in the company's condulets and other electrical equipment.

(402) PCM TELEMETRY SYSTEM. Epsco, Inc. Brochure, 4 pp. Describes a family of modular building blocks and how they have been used to assemble integrated air/ground data gathering systems. Photo shows system developed for gathering data used in the evaluation of flight tests of a modern jet fighter-bomber.

(403) TEMPERATURE CONTROLS. U. S. Testing Co., Inc. Bulletin SIS 9000 series, 2 pp. Announces three new electronic temperature controls designed for use by the chemical processing industries. Models include two relay types and a proportioning type. A transistorized relay, designed for use with the above controllers, is also briefly described.

(404) PLASTIC CABLING. Plastic Products Div., International Resistance Co. Bulletin S-9, 8 pp. Covers the design features, specifications, and applications of a multiconductor flat-wire cable; multilayer circuitry; and flexible etched cable, circuits, and laminates.

(405) TIMING DRIVE SELECTION. T. B. Wood's Sons Co. Bulletin 21103, 8 pp. Entitled "5 Simple Steps to the Selection of Timing Belt Drives," this bulletin gives a method involving a minimum of mathematics for the selection of a drive to fit any application. Bulletin includes five sets of curves for drive-width selection.

(406) AERODYNAMIC INSTRUMENTS. Flow Corp. Bulletin 50, 4 pp. Short form catalog illustrates and describes a line of aerodynamic and random signal instruments. Included are hot wire anemometer systems and probes, micro-manometer, a static pressure probe, and a random signal voltmeter and correlator.

(407) CHART PAPERS. Judson Bigelow Sales Div., Techni-Rite Electronics, Inc. Catalog, 14 pp. Data includes a complete listing of replacement charts for all makes and models of recorders, with cross reference to recorder manufacturer's model numbers.

(408) NUMERICAL CONTROL SYSTEMS. Ex-Cell-O Corp. Bulletin 506-0125, 12 pp. Contains some general information on numerically controlled machine tools and goes into more detail on three specific types of machines in use today. All systems described use continuous path control methods.

(409) STEPPING MOTORS. The Superior Electric Co. Slo-Syn data sheet

CONTROL ENGINEERING

No. 1, 4 pp. Full-color bulletin shows how the company's Slo-Syn synchronous motors have been used as dc stepping motors. Rotor-stator diagrams accompany the description of the step principle. Other illustrations include characteristic curves, wiring diagrams, and switching sequence tables.

(410) **LANGUAGE TRANSLATOR.** Hermes Electronics Co. Technical bulletin, 4 pp. Describes various types and techniques of code conversion and the relative merits of different numerical codes which may be employed by the design engineer. Also includes a discussion on the theory of numerical codes.

(411) **COMPACT SWITCHGEAR.** I-T-E Circuit Breaker Co. Bulletin 2801-A, 20 pp. Describes in detail a completely redesigned line of 4,160-volt, metal-clad switchgear, said to be the most compact in the electrical industry. To aid engineers, designers, and purchasing agents, bulletin lists construction and performance features, ratings, and dimensions.

(412) **INDUSTRIAL TEST EQUIPMENT.** Control Engineering Co. Brochure, 6 pp. Pictorially presents a diversified line of precision test equipment for aircraft, missile, automotive, and general industry applications. Features universal and combination test equipment using hydraulic, electronic, pneumatic, and mechanical components.

(413) **THERMOCOUPLE WIRE.** Minneapolis-Honeywell Regulator Co. Catalog C-100-2, 12 pp. Contains information on a complete line of thermocouple wire and extension wire, both bare and insulated. Also lists prices and ordering directions.

(414) **SIMPLE FLOWMETER.** Rotron Controls Corp. Catalog sheet CM-47, 2 pp. Discusses, in elementary terms, the new vortex-velocity principle of fluid flow measurement and the operation of Rotron's line of Whirl-Flo meters. Schematic diagram and photo illustrate the text.

(415) **DC POWER.** General Electric Co. Bulletin GEA-669A, 12 pp. Lists the features, operation, and applications of GE's custom-built dc power supplies for computer, aircraft, missile, military, and special applications. Publication includes photos, load current graphs, and a comparison table of different types of power supplies and power supply systems.

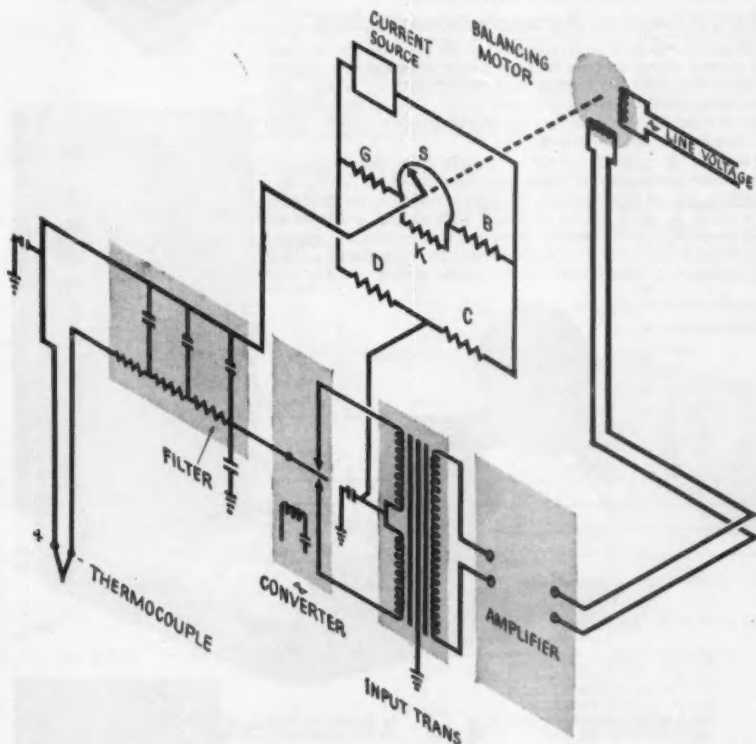
(416) **OPTICAL PYROMETERS.** Leeds & Northrup Co. Data Sheet ND42-35(1), 6 pp. Describes and illustrates the construction and operation of a potentiometer-type optical pyrometer, graphically showing the application of the "disappearing-filament" method of temperature measurement. Lists the standard instruments and ranges, together with accessory equipment for various specific measurements.

(417) **DENSITY GAGE APPLIED.** Ohmart Corp. Data sheet. Describes how some costly problems of sludge handling have been solved by means of a nuclear density gage. Discusses the design factors which must be considered when applying this type of instrument to sludge measurement and control.

(418) **METER COMPENSATION.** Bailey Meter Co. Bulletin 21, 2 pp. Describes pneumatic and electric transmission systems in which both pressure and tem-



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What leads Speedomax G users to expect — and get — fast response . . . fast balancing . . . fast control action?

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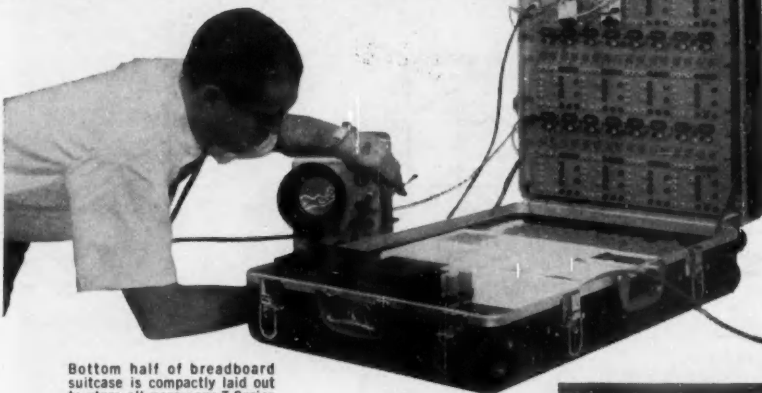
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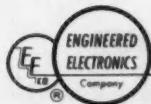
Bottom half of breadboard suitcase is compactly laid out to store all necessary T-Series circuit modules, circuit cards, patch cords, and compatible power supplies.

EECO T-Series breadboard equipment is available in both suitcase and rack-mounted types. Breadboard Kits of any degree of complexity can be built up in stages, according to the specific panels and number of circuits incorporated. Compatible interconnections between racks or suitcases further enable the designer to expand the equipment into a complete systems development console. Compatible solid-state, convection-cooled power supplies are also available in two different models: ZA-720 is a dual 12-volt, 5-amp supply; ZA-721 is a 12-volt, 1-amp plug-in power supply.

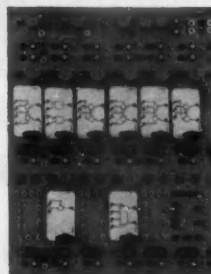
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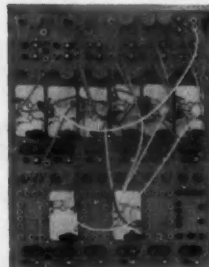
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Circuit cards are selected according to the system it is desired to breadboard and placed on the panel in alignment with the jack pattern. Corresponding T-Series circuit modules are plugged in above each card.



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Bulletins & Catalogs

perature compensation must be made. Schematics illustrate the hardware used, and literature reference tables refer to detailed product specifications.

(419) **CIRCUIT BREAKERS.** Wood Electric Corp. Catalog, 8 pp. Provides information necessary for the proper selection of circuit breakers for use on large aircraft and in industrial electronic systems. Standard and miniature thermal units are covered as well as push-pull and toggle types.

(420) **AIR VALVES.** Airmatic Valve, Inc. Bulletin 91024, 20 pp. Completely illustrated brochure describes the company's electrically-operated valves.

(421) **COMPUTER CONTROL.** Royal McBee Corp. Application Report No. 16, 8 pp. Covers refinery design on a desk-sized computer. Explains in detail how a LGP-30 handles the design of a plant with multiple feed streams and prints out component material balances of up to 54 streams of nine components.

(422) **FREQUENCY DISCRIMINATOR.** Magnetic Research Corp. Data sheet 91-10510, 2 pp. First in a series of new data sheets, this publication contains complete details on a new 115-volt, 400-cycle frequency discriminator with a 0 to 5-v dc range.

(423) **REACTOR PROFILEMETER.** Physical Sciences Corp. Technical manual, 3 pp. Describes the Model 303 profileometer unit which measures surface variations to 0.005 in., profiles, or other measurements involving displacement and is designed to operate in a nuclear environment, under water, and at temperatures up to 1,000 deg F.

(424) **TRANSISTORIZED POWER.** Valor Instruments, Inc. Brochure, 4 pp. Describes the exclusive instantaneous electronic lock-out feature of a new transistorized twin power supply, the Model PS202MB. Also covers other features such as automatic reset, continuously variable current limiting, and voltage indicated before connected to load.

(425) **PROGRAMMING DETAILS.** Clary Corp. Brochure provides details on the programming and operation of the company's new DE-60 computer, a low cost, compact, general purpose, transistorized machine designed to handle procedural routine without long, involved input preparation.

(426) **TRIGISTOR APPLIED.** Solid State Products, Inc. Applications bulletin AS-100. Shows how low-level logic operations and high-level output can be combined in a single circuit with the company's Trigistor element.

(427) **BUTTERFLY VALVES.** Mason-Neilan, Div. of Worthington Corp. Supplements Catalog No. 307. 4 pp. Pictures typical variations of light and heavy duty wafer style butterfly valves and describes three basic body designs. Also shows a variety of valve actuators and special arrangements, including spring-diaphragm actuators, auxiliary handwheels, special shaft extensions for liquid oxygen service, cylinder actuators, electric actuators, and positioners.

NEW PRODUCTS

capacity of 0.5 amp-hr with a maximum current of 10 amps. The cell will maintain its terminal voltage of 1.4 volts under a 2-amp load; no load voltage is 1.86 volts.—Cook Batteries, Subsidiary of Telecomputing Corp., Denver, Colo.

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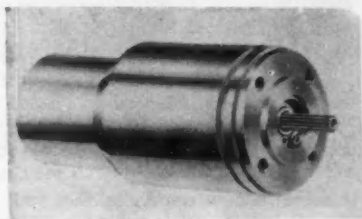
ACTUATORS & FINAL CONTROL ELEMENTS



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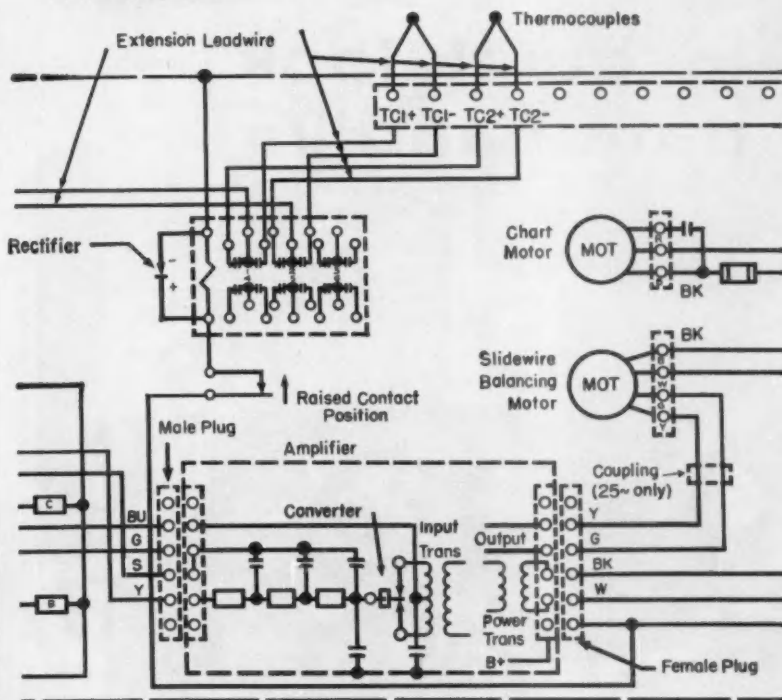


FOR HIGH TEMPERATURES

Shown above is a new Size 11 servo-motor that has been designed to meet



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Behind Speedomax® G performance: CLEAN MEASURING CIRCUITS

Why does Speedomax G maintain its precise calibration for so many years, even under difficult service conditions?

One of the reasons is the care taken in the development and manufacture of Speedomax G measuring circuits. Over 300 circuits are available . . . and each takes maximum advantage of electronic null detection, non-inductive wiring and proper shielding.

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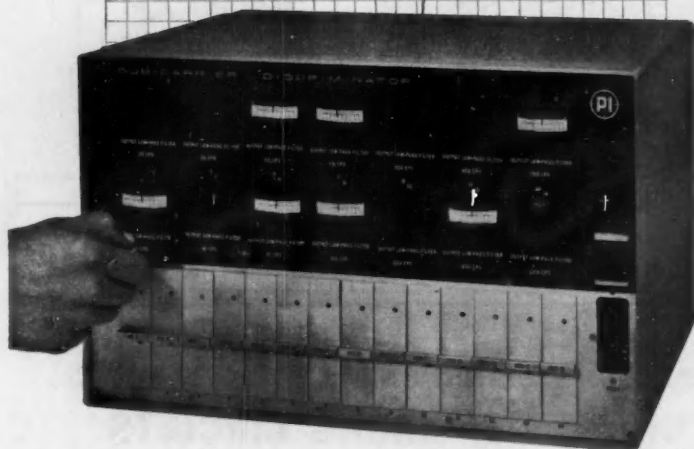
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sub-carrier discriminator

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178 CIRCLE 178 ON READER SERVICE CARD

NEW PRODUCTS

military environmental specifications. The inertially damped unit is suitable for use in high speed or high gain servosystems.

Characteristics:

No load speed: 5,800 rpm
Torque at stall: 0.60 oz-in.
Rated voltage: 115 volts rms, 400 cps for fixed phase; 70 volts for control phase
Flywheel magnet inertia: 2.0 gm-cm²
Flywheel magnet damping factor: 80 dyne-cm/rad/sec
Corner frequencies: 2.3 cps for F₁, 6.4 cps for F₂, 23.3 cps for F₃
John Oster Mfg. Corp., Avionic Div., Racine, Wis.

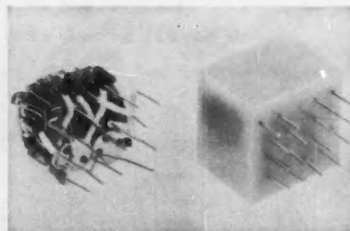
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BRUSHLESS DC MOTOR

Dc input is commutated by means of transistors, which form the heart of the oscillating system, in a new brushless dc motor. In earlier transistor-commutated dc motors, the motor has constituted the load on the oscillator. In this new design the winding in the motor is an integral part of the circuit; there is no separate toroid. Motor speed can be infinitely varied—by changing voltage input—through a range limited only by mechanical factors due to centrifugal forces. Small units can be operated to 250,000 rpm.—Yuba Dalmotor Div., Yuba Consolidated Industries, Inc., Santa Clara, Calif.

Circle No. 333 on reply card

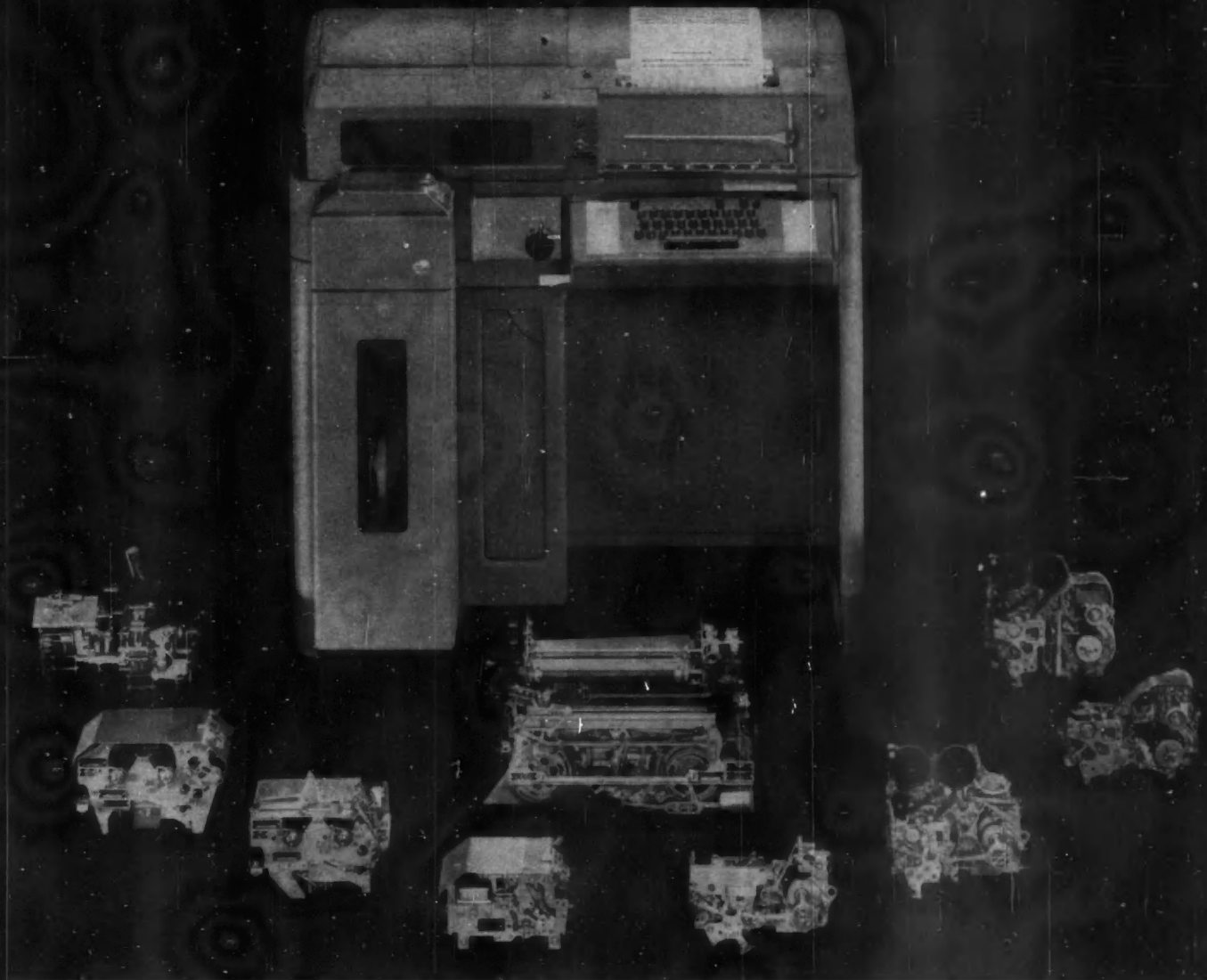
COMPONENT PARTS



ENCAPSULATED BLOCKS

For use in computers, digital data systems, digital frequency dividers and frequency standards, logic networks, etc., these epoxy encapsulated digital building blocks are available in 10

CONTROL ENGINEERING



Complete message center in one Teletype machine

A complete message center in a compact cabinet, with a choice of components to best meet your individual needs—that's the story of the Teletype Model 28 automatic send-receive set.

It provides facilities for sending and receiving on message paper or sprocket-fed business forms. In addition, there is a choice of four different tape reader and four different tape punch components—for preparing punched tape and for sending and receiving with tape.

The flexibility of the set is further broadened by a built-in control unit, the "stunt box," which may be equipped for a wide variety of extra features and switching duties—eliminating the need for external apparatus often required for such functions.

The ASR set is a compact, efficient tool to speed communications and cut costly paperwork. Teletype Corporation manufactures this equipment for the Bell System and others who require the finest in data communications equipment.



Typing Tape Punch



Tape Reader



Send-Receive Page Printer



Automatic Send-Receive Set

FREE Model 28 line folder. Write Dept. 26K,
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NEW PRODUCTS

basic types and 15 variations of modules. Packing density is typically 35 standard components per cu in. (50,000 per cu ft). All modules are 0.8 in. high and 1.0 in. long, while width varies in multiples of 0.2 in. from 0.4 in. to 1.0 in.—Delco Radio Div., General Motors Corp., Kokomo, Indiana.

Circle No. 334 on reply card

10-STAGE PHOTOMULTIPLIER

A new, 5-in. diam, 10-stage photomultiplier tube is guaranteed by its manufacturer to withstand 40-g shock of 11 millisec duration and 10-g vibration of 0-2,000 cps in each of three planes. Faceplate is planoconcave with S-11 photocathode (visible response) deposited on a curved surface for excellent uniformity of response across the face, due to very high photoelectron collection efficiency. Linear output current as high as 200 ma for 100-millimicrosec pulses is possible. Price: \$150.—Electron Tube Dept., CBS Labs., Stamford, Conn.

Circle No. 335 on reply card

SCR CONTROLLER

Failsafe full range phase shift control for silicon controlled rectifiers of all makes and ratings is possible using the recently announced Silicontrol. The unit provides complete control of one or two SCR's in a small, compact, ready-to-use package eliminating involved circuitry. Supersensitive phase shifting network applies 60-cycle steep pulses of constant amplitude to rectifier gates and varies their phase angle over a full 180 deg to control the rectifier gates and varies their phase angle over a full 180 deg to control the rectifier output from zero to maximum. Pulse rise time is only a few microseconds.—VecTrol Engineering, Inc., Stamford, Conn.

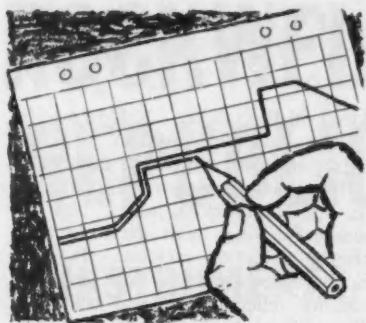
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ACCESSORIES & MATERIALS

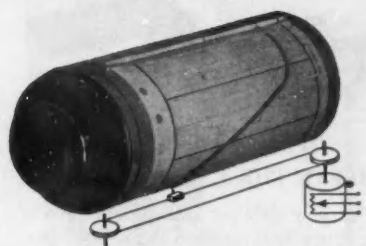
SINGLE CRYSTAL NaF

Grown by a vacuum process, single crystal sodium fluoride is now being

CONTROL ENGINEERING



Plot your program
with a pencil on
ordinary graph paper



DATA-TRAK®
will **follow** it

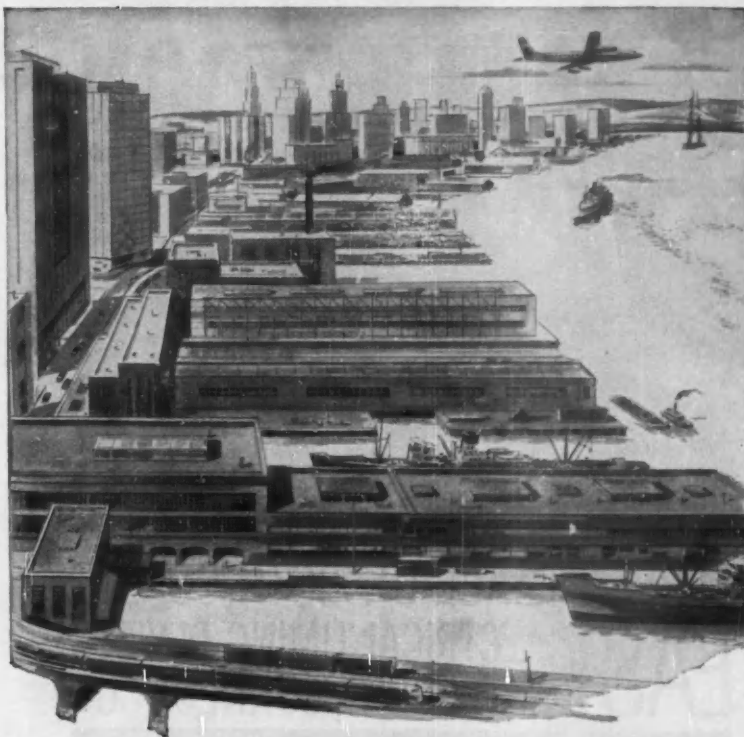


Now, with only an ordinary graphite pencil and graph paper, you can feed program instructions to automatic process controls. Data-Trak follows pencil-drawn graphs anyone can prepare. High degrees of accuracy and reliability result from use of unique capacitive curve-following principle. Potentiometer output is proportional to drawn curve.

Graphs last indefinitely because stylus doesn't touch the paper. Data-Trak drum speed is variable, can even be programmed automatically. Drum rotates continuously on some models for cyclic programming.



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CIRCLE 204 ON READER SERVICE CARD
OCTOBER 1960



The Application of DATA PROCESSING TECHNIQUES

... to reduce man hours and increase production, in industrial and commercial operations, is a familiar problem to Analex® Systems Division engineers.

This group has worked together for almost ten years, using digital techniques in the development of logical solutions to special problems of control, timing and data handling. They are also experienced in the development of specialized tracking, timing, communications and test systems for military applications.

Finished equipment required for these systems may be produced by the customer or by the Analex manufacturing facility under the direct supervision of the engineering group. This division is staffed by technicians and skilled craftsmen who have specialized in the production of unusual and sophisticated data processing equipment.

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CIRCLE 181 ON READER SERVICE CARD 181

THE A. W. HAYDON COMPANY

MIRROR IMAGE ON BOTH COASTS
EAST ELECTRICAL TIMING DEVICES
WATERBURY, CONNECTICUT

ELECTRONIC TIMING DEVICES WEST
CULVER CITY, CALIFORNIA WEST

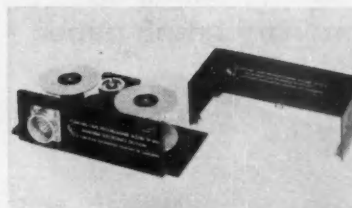
Have it your way: electronic or electro-mechanical timing devices and test equipment. ■ The A. W. Haydon Company will design and manufacture either type...or both...to your rigid specifications. And with the same precision, compactness and high reliability as always. ■ For electro-mechanical devices call on our timing specialists at Waterbury, Conn. If your requirements are electronic, our Culver City, Calif. plant can meet your needs. ■ On either coast...on both coasts...there's only one A. W. Haydon.

THE A. W. HAYDON COMPANY

NEW PRODUCTS

placed on the market. NaF transmits light to about 12 microns in the infrared region and down to 185 millicrons in the ultraviolet region. Since it also has low solubility in water, NaF is suitable for windows in ultraviolet and infrared detection systems. It may also be evaporated as a thin film and used for reflection-reducing coatings. —Semi-Elements, Inc., Saxonburg, Pa.

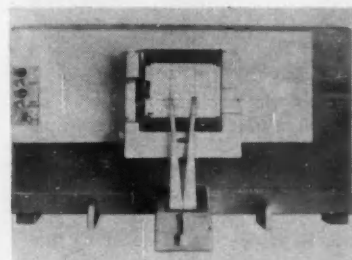
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MEETS THE ENVIRONMENT

This new airborne tape programmer is designed to withstand the severe operating conditions encountered in missiles, aircraft, and ordnance equipment. It has a tape capacity of 75 ft of 35-mm Mylar film, equivalent to a 20-min program at standard 0.748 ips. Contacts are rated at 0.4 amps. The unit weighs 26 oz, measures 2 x 3 x 6 in. Price in quantities of 1-3:\$900.—Anaheim Electronics Div., Electronic Engineering Co. of Calif., Santa Ana, Calif.

Circle No. 338 on reply card



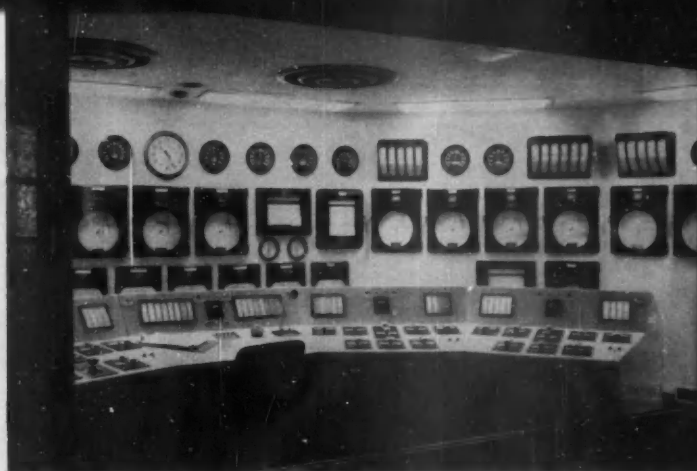
INTEGRATES CHART RECORDS

For use with the charts produced by the manufacturer's strip chart recorders and with conventional round charts, this new integrator provides three values from a single run. It not only computes the chart extension for differential and static pressure, but it also provides readout values for the average absolute static pressure and the average differential pressure. —American Meter Co., Erie, Pa.

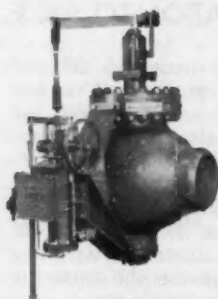
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ROCKWELL- REPUBLIC

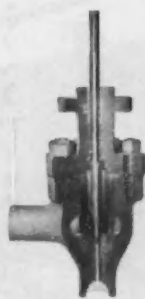
INSTRUMENTS, CONTROLS, AND VALVES



Rockwell-Republic Control Systems. Republic engineers and furnishes equipment for both electronic and pneumatic control systems, for use on large central stations, package boilers, process industries, and steel mills. Republic has installed more than 125 electronic control systems since the first one in 1949. They total more than 400 unit-years of operation. These central systems automatically control steam pressure, combustion, furnace pressure, excess pressure, boiler level, and other variables.



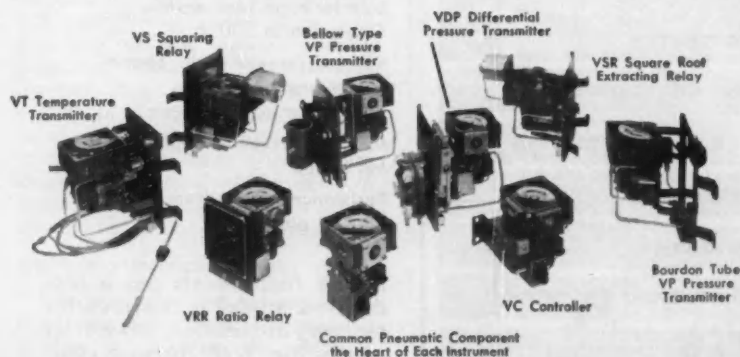
Steam Dump Valve. Series 700 double-seat valve (600 psi) with Series 73 positioner. Valve shown used in nuclear power plant to dump steam to condenser when steam must by-pass turbine.



Quick-Change Trim V-10 Valve. For severe services up to 4500 psi, newly improved regulating valve features quick-change trim that allows dismantling and reassembly within minutes without removing valve from line.



Improved Final Drive Unit. Operates valves, dampers, inlet vanes, etc., in response to either pneumatic or electronic signals from remote control station. Can also be operated manually. Power is pneumatic.



Null-Balance-Vector Pneumatic Instruments. When used with each other, Rockwell-Republic null-balance-vector instruments offer the special advantages

of a high rate of inter-changeability of parts and simplified training requirements because a common pneumatic component is used throughout the line.



M/A Control Stations. Republic offers a complete line of compact, panel mounted control stations for use with Null-Balance-Vector instrument control systems. These control stations are made in several types to accommodate a wide variety of pneumatic control applications.

In addition to the above items, a complete line of Rockwell-Republic instruments and controls including Desuperheaters, Electric Transmitters, Flow Meters, CO₂ meters, valves, and others is available. Write to Republic Flow Meters Company, Subsidiary of Rockwell Manufacturing Company, 2240 Diversey Parkway, Chicago, Illinois.



CIRCLE 183 ON READER SERVICE CARD



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GRADUATE TRAINING CENTER

FREQUENT SCIENTIFIC COLLOQUIA

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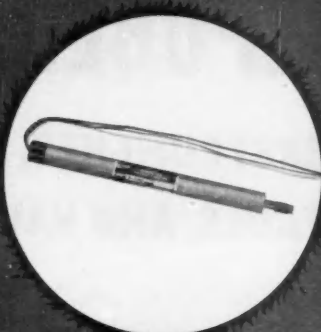
... these are some of the Doorways
to Knowledge at Los Alamos.

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scientific laboratory
OF THE UNIVERSITY OF CALIFORNIA
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SERIES 3



**Wirewound Feedback Potentiometers
FOR OPERATION TO 500°F**

Edcliff Instruments' Model 3-120 linear motion servo potentiometers are designed for use with hydraulic and electrical actuators in Missile, Aircraft and Remote Control Systems. Only 1/2 inch in diameter, the new, all metal construction instruments may be installed inside the actuator shaft to conserve space.

Small Size: Only 1/2 inch diameter.

Standard Stroke lengths from 1 to 5 inches.

Built for High Temperature Operation to 500°F.

Rugged, insensitive to Shock and Vibration.

All Metal Construction.

Meets or exceeds applicable Mil Specs.

Resistance Ranges from 100 to 50,000 ohms/inch.

Edcliff Instruments has a production model potentiometer for every application. Let Edcliff supply the "feel" for your guidance system. Write today for your free application data catalog.



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Monrovia, California

**CIRCLE 205 ON READER SERVICE CARD
CONTROL ENGINEERING**

ABSTRACTS

Excerpts From NASA Report

From the "Second Semiannual Report of the National Aeronautics and Space Administration", covering the period April 1 to September 30, 1959. NASA Headquarters, Washington, D. C. Released July 22, 1960.

The following excerpts, taken verbatim from NASA's report to Congress, cover some of the administration's activities in the fields of automatic control and instrumentation:

Attitude control and stabilization

Research studies of attitude control and stabilization systems for spacecraft involve: 1) spelling out system requirements, 2) developing methods of determining and maintaining attitude reference in space, and 3) devising techniques of providing control forces. In addition, procedures have to be developed to evaluate control system performance and reliability in a simulated space environment.

System requirements

To match stabilization requirements with attitude control system capabilities, possible methods must be compared with mission requirements for accuracy, weight, power, simplicity, and reliability.

An initial study at Langley for a manned space station indicated that a stabilization system should incorporate the following features: 1) attitude reference supplied by a solar seeker, with gyro to maintain attitude during periods of darkness in the shadow of the earth; 2) gas jets to get the vehicle pointed in the right direction and to damp major perturbations (disturbances) that may occur when, for example, a space ferry vehicle arrives or departs; and 3) inertia wheels to reduce the effect of minor disturbances.

Attitude reference-sensors

Sensing devices that can provide attitude reference—that is, determine the position and direction of a vehicle in space—by detecting radiation from the earth, moon, and sun are being investigated. Two different types of horizon scanners have been designed, both of which are compact, lightweight, rugged, and require only small amounts of power. One type is sensitive to light waves and is limited to daytime use; it is intended primarily for vertical probes. The other, for day or night use, employs heat-sensitive detectors and a

NEW!

GREATER...

- OUTPUT
- STABILITY
- ACCURACY



- Multi-column
- Smaller size
- Hermetically sealed

Cox and Stevens LOAD CELLS

For greater accuracy and stability in all types of weight and force measurement, specify new Cox and Stevens hermetically sealed load cells. Sixteen strain gages in multi-column design provide up to 250% greater output, improved stability and better uniformity between cells. Capacities range from 500 to 200,000 lbs. All cells with 30 feet of special moisture- and chemical-resistant cable in stainless steel jacket.

Cox and Stevens' fifteen years experience in designing and manufacturing load cells, plus dead weight testing facilities which make possible calibration to higher accuracies, assure maximum reliability. Write for technical bulletins.

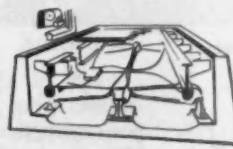
TYPICAL SPECIFICATIONS

1. Recommended Input:20 volts
2. Change in Output, No Load to Full Load:1.750 \pm .1% millivolts/volt input
3. No Load Output: \pm .25% of full load output
4. Output Linearity:0 to \pm .20% of full load output
5. Temperature Effect on Cell Output (15 to 115°F): \pm .0008%/°F of output at applied load
6. Temperature Effect on No Load Output (15 to 115°F): \pm .0013%/°F of full load output
7. Input Impedance at 75°F:450 \pm 1 ohms
8. Allowable Load:225% of rated capacity
9. Deflection Under Rated Load:Less than 0.003"

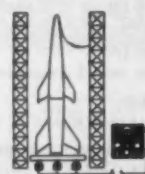
APPLICATIONS



BATCH WEIGHING



PLATFORM SCALES



MISSILE WEIGHING

also Continuous Weighing • Proportioning • Truck, Tank, and Crane Scales • Thrust Measurement

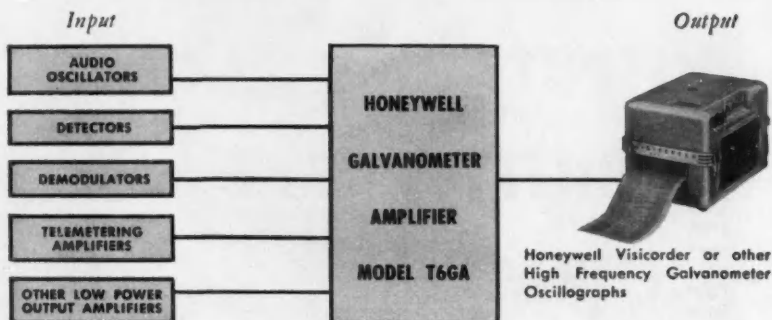
53R

neptune

REVERE CORPORATION OF AMERICA/Wallingford, Conn.
One of Neptune Meter Company's Electronic subsidiaries

NEW GALVANOMETER AMPLIFIER

Strengthens Low Power Signals to Drive High Frequency Oscillographs



Galvanometer Amplifier, Model T6GA-1, measures 3½" high, 19" wide, 15½" deep.

DESCRIPTIVE DATA

VOLTAGE GAIN:
Adjustable from 0 to 1.0

OUTPUT (37 OHM LOAD):
± 2.4 volts at 65 ma d-c to 8 Kc, limits at ± 100 ma.

OUTPUT IMPEDANCE:
2 Ohms d-c to 10 Kc

CONTROLS:
6 GAIN controls, 1 Power ON-OFF switch

INPUT IMPEDANCE: 47 K

ISOLATION:
Individually floating channels for use with ungrounded loads

NOISE:
Less than 3 mv peak-to-peak

DRIFT:
Less than 3 mv/°F

POWER REQUIREMENTS:
115 volts ± 10 volts, 50 to 440 cps, 45 watts

With Honeywell's new Galvanometer Amplifier, Model T6GA-1, high frequency oscillographs can now be operated directly by low power input sources of 1 volt or more. These inputs, some of which are shown in the diagram above, should have output impedances of 10 K or less although higher source impedances can be tolerated. Noise and drift are indistinguishable on the recorded output when the galvanometer-amplifier combination has a maximum sensitivity of 1 inch per volt.

The Model T6GA-1 is a compact, six channel, three stage transistor d-c amplifier with overload protection to eliminate both danger of transistor damage and galvanometer burnout.

Each of the six amplifier channels is isolated from ground by individual floating power supplies. Write for Bulletin BS-T6 to Minneapolis-Honeywell, Boston Division, Dept. 34, 40 Life Street, Boston, Mass.

Honeywell



Industrial Products Group

SINCE 1885

ABSTRACTS

system of rotating mirrors; it will operate at altitudes of some 3,000 miles from the earth. This unit can be packaged within a cylindrical container that is 3 x 5 in.

A solar sensor comprised of two pairs of silicon cells, with each pair connected across both branches of the circuit, has been designed and tested. The sensor was able to detect radiation over a wide angle (± 120 deg) and showed high sensitivity when properly aimed; accordingly, a means for automatically adjusting the pointing action of the sensor has been devised.

Feedback control systems research

Research to design automatic control systems giving the desired vehicle response and stability is in progress. This is primarily analytical work, using mathematical models of aircraft, missiles, and space vehicles.

Areas in which significant progress has been made in the last 6 months are: 1) physical size of the power actuator (control surface servo for aircraft; jets, inertia wheels, rockets, etc., for spacecraft) and its effect on controller design; 2) effects of extreme variations in aerodynamic pressures, speed, and altitude throughout a given flight (flight tests to confirm results are underway); 3) errors on a radar seeker resulting from deflections of the radar signal as it passes through the radome (special nose enclosure) on a guided missile. These errors, heretofore, have caused large target-miss distances, particularly at high altitudes. A technique has been developed which, when incorporated into the vehicle guidance system, substantially reduces the miss distance.

Rocket-engine thrust control, stability, and throttling

In general, when the thrust of a rocket engine is reduced (as may be required, for example, in landing a manned vehicle on the moon), violent oscillations occur in fuel feed and combustion. The problem of reducing these oscillations has been attacked at the Lewis Research Center in two ways: by directly testing engines with controls derived from theory and by studying the contribution of each component of the rocket engine to instability. Specifically, fast-acting regulators were used to control a 5,000-lb. thrust hydrogen-fluorine engine over a range from full thrust to one-tenth thrust, and to start and stop the engine reliably without harming it. This work is now being extended to hydrogen-oxygen engines.



GD700 SERIES GAS-O-DOME REGULATORS

Models in bronze or stainless steel
Pilot operated type
Max. inlet: 7000 to 10,000 psig.
Outlet range: 10-150 to 400-7000 psig.
Flows to 250 scfm.
Low torque: 35 inch-lb. at 7000 psig.
Panel mounting
Bulletins R12 and R18.



LR SERIES LOADER REGULATORS

Models in bronze or stainless steel
Max. inlet: 7000 to 10,000 psig.
Outlet range: 5-200 to 200-10,000 psig.
Flow: 10 scfm.
Low torque: 35 inch-lb. at 7,000 psig.
60 inch-lb. at 10,000 psig.
Panel mounting
Bulletins R11 and R17



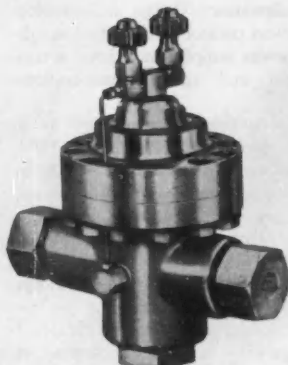
LV-10 LOADER VALVE

Made in bronze only.
Inlet and outlet: 7000 psig.
Flow: 10 scfm.
Fast finger-tip control:
30° clockwise, loads;
30° counter-clockwise, bleeds.
Panel mounting
Bulletin LV-10



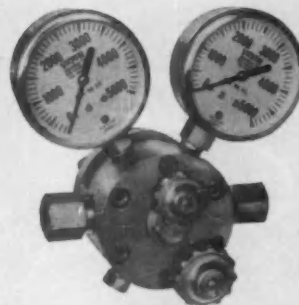
BPR SERIES BACK PRESSURE REGULATORS

Models in bronze or stainless steel
Adjustable relief ranges: From 25-500
psig. to 2000-10,000 psig.
Panel mounting
Bulletin R19



GD90, GD100A AND GD200A SERIES GAS-O-DOME REGULATORS

Models in bronze or stainless steel
Compensated, high-flow type
Max. inlet and outlet: 6000 psig.
Flows to 80,000 scfm.
Remote control and/or
panel mounting provisions
Bulletin R18



GD60 AND 80 SERIES GAS-O-DOME REGULATORS

Models in bronze
(stainless steel on request)
Inlet and outlet range: 2500 to 10,000 psig.
Flows to 1500 scfm.
Remote control and/or
panel mounting provisions
Bulletin R10A

VICTOR

High pressure gas controls

Victor offers you choice of these and many other gas regulators for a wide variety of applications.

All come cleaned for oxygen service; LOX cleaned when specified. Operating temperature ranges: -67° F. to +250° F. (storage -80° F.) Modifications for special applications. Write now for Victor High Pressure Regulator bulletins and Regulator Inquiry Form 361A.

Mfrs. of high pressure and large volume gas regulators; welding & cutting equipment; hardfacing rods; blasting nozzles; cobalt & tungsten castings; straight-line and shape cutting machines.

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CIRCLE 187 ON READER SERVICE CARD

BUILD ON...

Eastern

CONTROL EXPERIENCE:

SERVO SYSTEMS

Typical assignment: design and develop a missile elevon control servo with a single hydraulic power supply and three actuators. Weight and space considerations critical.

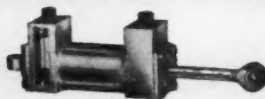
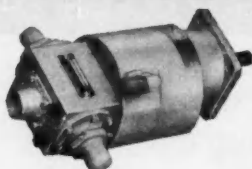
Solution: a system designed and built around the Eastern E/HS 5 type 100A hydraulic power supply, using a 400-cycle motor. Minus motor, but including pump, reservoir, expansion chamber, pressure regulating valve and filter, the supply weighs only 2.6 lbs.

Eastern achieved a 20% saving in hydraulic power supply capacity by the use of one of its own *pulse length modulated* single-stage servo valves, manifolded to each actuator. Zero first stage leakage, zero hysteresis, plus the high response and efficiency which characterize this valve contributed to the successful meeting of the demanding requirements.

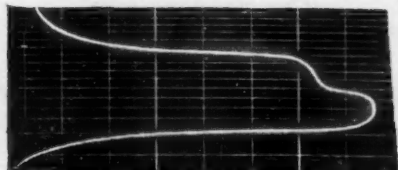
Specifications:

force level: 300 lbs.
total stroke: 1/2 in.
max. velocity: 1.5 in./sec.
time constant: 0.1 sec.
max. actuator width: 1.25 in.

For genuine contributions to the solution of your servo problems, call in the Eastern engineer.



servo-valves • fuel controls • actuators



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NEW BOOKS

Classic Redone

PRINCIPLES OF DIRECT-CURRENT MACHINES. Alexander S. Langsdorf, Washington University. 363 pp. Published by McGraw-Hill Book Co., Inc., New York. \$8.50.

The sixth addition of this well-known text, although abbreviated considerably because the subject of energy converters is now commonly allotted limited time in electrical engineering curricula, is still a sufficiently rigorous and comprehensive presentation of the principles of direct current machines. Compared with its 1940 predecessor, many portions of the book have been brought up to date by the addition of new material, particularly in Chapter 7 on Control of Motors and Generators, and by the liberal use of new illustrations such as graphs, wiring diagrams, and photographs. Moreover, arrangement of the subject matter and its format has been strikingly improved.

A brief introductory chapter dealing with electromagnetic theory and the relations between rationalized mks and cgs systems of units is presented primarily to serve as a review and because, as the author suggests, it has an important bearing on the design, construction, and operation of electrical machines. This short chapter of but 44 pages is in contrast with the more ambitious treatment of "fundamentals" covering five chapters and 264 pages in the previous edition.

Considerable emphasis is placed upon generator and motor principles and how they affect the operating characteristics of this type of equipment. These principles involve such important discussions as armature windings and the generation of electromotive force, the theories of field excitation, armature reaction and commutation, the fundamentals of efficiency, rating and heating, and, where an understanding of these topics may be further augmented, a good sprinkling of machine design procedures. Applications are treated well, though sparingly, in chapters devoted to motor control and special machines.

Graphical methods are consistently employed by the author to explain and predict general machine performance. This practice is used to good advantage in dealing with nonlinear types of magnetic circuits, although the results of such analyses are to yield qualitative relations rather than quantitative accuracy. Moreover, such graphical pro-

From the home of
Planned Pioneering
THE MODEL 711

Strainistor

Ultra Sensitive Strain
Sensing Elements.
60-70 times greater
sensitivity than other
metal strain gauges.



**FIRST
COMMERCIALY
AVAILABLE**

- Strain sensitivity 120-140
- 120 Ohm nominal resistance
- Resistance change linear with strain.
- Negligible hysteresis
- Suitable for static and dynamic measurements.
- Combination mounting and handling fixture with each Strainistor.

*Manufacturers of light beam
galvanometers and magnetic
assemblies since 1945.*



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OCTOBER 1960

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**for converting any 4 bit code
to decimal illuminated display**

Performs better



...Costs less

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Converter, Model 260,
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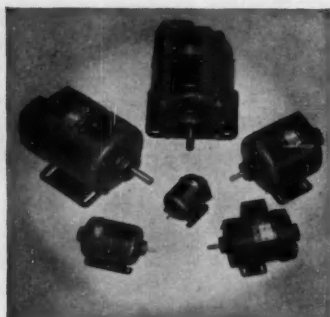
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PC/2C	DPDT 15A	6, 12, 24, 115, 220		6, 12, 24, 110	16		
PC/3C	3PDT 15A	6, 24, 115, 220		6, 12, 24, 110	250		
PC/4C	4PDT 15A	6, 24, 115, 220		6, 12, 24, 110	400		
PG/2C/6VA	DPDT 15A	6 VDC	16				
PG/2C/24VA	DPDT 15A	24 VDC	16				
PG/2C/115VA	DPDT 15A	115 VDC	16				
PG/2C/220VA	DPDT 15A	220 VDC	16				
PG/2C/6VD	DPDT 15A	6 VDC	16				
PG/2C/12VD	DPDT 15A	12 VDC	16				
PG/2C/24VD	DPDT 15A	24 VDC	16				
PG/1Z/6VD	SPDT 30A	6 VDC	16				
PG/1Z/115VA	SPDT 30A	115 VDC	16				
POWER TRANSFER TYPES							
PH/1A/6VD	SPSTNO 20A	6 VDC	16				
PH/1A/115VA	SPSTNO 20A	115 VDC	16				
PH/1C/6VD	SPDT 20A	6 VDC	16				
PH/1C/115VA	SPDT 20A	115 VDC	16				
PV/1A/6VD	SPSTNO 30A	6 VDC	16				
PV/1A/115VA	SPSTNO 30A	115 VDC	16				
PV/1C/6VD	SPDT 30A	6 VDC	16				
PV/1C/115VA	SPDT 30A	115 VDC	16				

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NEW BOOKS

cedures help to impress the student with the effects of changing speeds, excitation, and loads, as well as the differences in the behavior of the various types of machines.

The book suffers from a lack of solved problems that illustrate theoretical discussions and derived equations. This seems to be a rather serious omission because, to this reviewer at least, students are not likely to be impressed too greatly by symbols, fundamental relationships and formulas unless these are shown to yield useful practical information. In addition, the illustrative example technique usually helps to give the student a feeling of confidence and an appreciation of electrical magnitudes and physical dimensions.

A fine set of problems and two appendices dealing with dimensions of electrical and magnetic units and free-hand flux plotting conclude the text.

C. S. Siskind
Purdue University

Statistics Primer

PROBABILITY, AN INTRODUCTION. Samuel Goldberg. 322 pp. Published by Prentice-Hall Inc., New York, N. Y. \$7.95.

This book deals with the fundamental mathematics of probability and its application using the language and notation of sets. The entire first chapter is devoted to the elementary mathematics of sets, and additional material on sets is presented throughout the text as the need for this information arises.

The book provides an introduction to random variables and probability distribution functions (including bivariate distributions, correlation, and sampling theory). Theory is presented for finite sample spaces only; this approach facilitates a careful, logical treatment of the essentials needed by all who use probability concepts—especially in statistics—and makes further study easier and more meaningful for students in mathematics as well as for those in other fields.

Since no material needing the use of calculus is included, the only prerequisite is a good background in high school algebra. There are 110 worked-out illustrative examples in the text, including discussions of population genetics, sampling inspection and OC curves, bridge and poker hands, baseball series, tests of hypotheses and power curves, and statistical decision-making problems.

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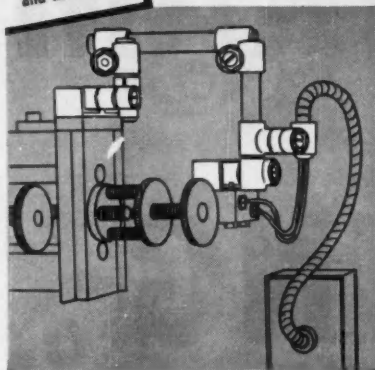
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MEETINGS**OCTOBER**

American Institute of Electrical Engineers, Fall General Meeting, Morrison Hotel, Chicago, Ill. Oct. 9-14
National Electronics Conference, Hotel Sherman, Chicago, Ill.

Oct. 10-12

Institute of Radio Engineers, Symposium on Adaptive Control Systems, Garden City Hotel, Garden City, N. Y.

Oct. 17-19

American Society for Metals, 42nd National Metal Exposition and Congress, Trade and Convention Center, Philadelphia, Pa.

Oct. 17-21

Second International Congress and Exhibition for Measuring Techniques and Automation (INTERKAMA), Dusseldorf, Germany

Oct. 19-26

Institute of Management Sciences, Seventh International Meeting, session on computers and simulation techniques, Hotel Roosevelt, New York City

Oct. 20-22

Institute of Radio Engineers, East Coast Aeronautical and Navigational Electronics Conference, Lord Baltimore Hotel, Baltimore, Md.

Oct. 24-26

Fifth Annual Conference on Non-Linear Magnetics and Magnetic Amplifiers, sponsored by IRE and AIEE, Bellevue Stratford Hotel, Philadelphia, Pa.

Oct. 26-28

Institute of Radio Engineers, Electron Devices Meeting, Shoreham Hotel, Washington, D. C.

Oct. 27-28

NOVEMBER

Institute of Radio Engineers, 13th Annual Conference on Electrical Techniques in Medicine and Biology. Theme: application of electronic techniques to analytical instrumentation, Sheraton-Park Hotel, Washington, D. C. Nov. 1-2

Sixth Annual Conference on Magnetism and Magnetic Materials, sponsored by AIEE and American Institute of Physics, Hotel New Yorker, New York Nov. 14-17

Nov. 14-17

Symposium on Engineering Applications of Probability and Random Function Theory, Purdue University, Lafayette, Ind. Nov. 15-16

Nov. 15-16

Institute of Radio Engineers, Mid-America Electronics Convention (MAECON), Hotel Muehlebach, Kansas City, Mo.

Nov. 15-16

American Society of Mechanical Engineers, Annual Meeting, Statler Hilton Hotel, New York

Nov. 27-Dec. 2

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WHAT'S NEW

(Continued from page 51)

Instrumentation, New Division In NBS Organization Changes

Recent changes in the organization of the National Bureau of Standards laboratories in Washington, D. C., have streamlined the bureau's operation. One change is the establishment of a new division, Instrumentation, with G. Franklin Montgomery as its chief. It comprises three sections from the Electricity and Electronics Div., a part of the Mechanical Instruments Section, and the Basic Instrumentation Section.

The new division will investigate the fundamental properties and limitations of instruments; of their components and materials; and of measuring, recording, and signal processing methods. It will investigate basic phenomena that may be applied to instrumentation and develop improved instrumental techniques, instruments, and devices. Other duties include providing scientific information and advice on instrumentation to other parts of NBS, other government agencies, and the public.

In other changes at NBS, William A. Wildhack, who was chief of the Office of Basic Instrumentation, becomes special assistant to the director. Joshua Stern replaces Wildhack and becomes chief, Basic Instrumentation Section (new name).

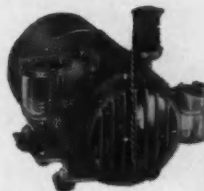
News of Other Companies In the Control Field

Chicago Aerial Industries, Inc. of Barrington, Ill. has scotched rumors of impending mergers. The firm told its stockholders in its quarterly report that several major corporations had asked to investigate merger possibilities but that no such agreements were under consideration. CAI espoused a policy of independence as in the best interest of its stockholders. One reported merger possibility had been Itek Corp. (CtE, Sept. '60, p. 266).

Analysts, Inc. is the first independent laboratory set up to recommend preventive engine maintenance based on analysis of sump oil. President of the Oakland, Calif., lab is Charles Jackson, developer of Pacific Intermountain Express' Emeryville oil lab (see CtE, June '60, p. 60). Nationwide 24-hr service is promised.

GPL Div. of General Precision, Inc., a subsidiary of General Precision Equipment Corp., has formed a new

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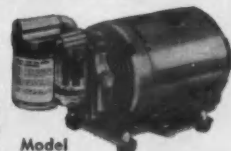
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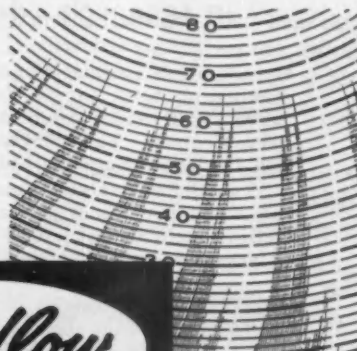
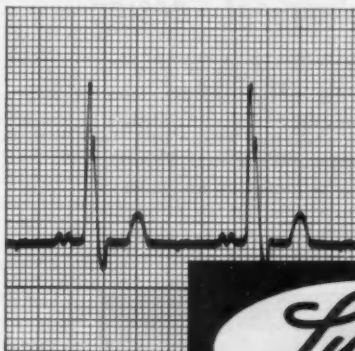


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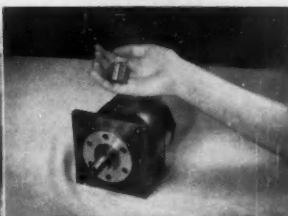
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WHAT'S NEW

Systems Div. Under the direction of William H. Heath, formerly head of GPL's Engineering Div. The Pleasantville, N. Y., unit has been formed as the result of the increasing importance of systems work at GPL.

Thompson Ramo Wooldridge, Inc. has formed a new division with the intriguing name of Educational Electronics Div. The Los Angeles firm has consolidated the educational sales groups of its subsidiary Magnetic Recording Industries and of its Dage Television Div. Commercial electronic products for schools will include closed circuit TV, language labs, teaching machines, recording systems, and what TRW calls electronic classrooms.

Minneapolis-Honeywell Regulator Co. has set up a new division to advance the state of the art in complex integrated control systems for industry and the military.

Temco Electronics & Missiles Co. is the new official name for Temco Aircraft Corp. following the merger of the Dallas firm with Ling-Altec, Inc. CtE, June '60, p. 45).

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The temperature recorder is a Varian G-11A with T-2 input chassis which has automatic reference junction compensation and plug-in range elements as shown. Other input chassis convert the recorder to general use. Fahrenheit or Centigrade charts available. For full details, write Instrument Division.



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OCTOBER 1960

WHAT'S AVAILABLE IN REPRINTS

The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient fileable form. Single copies of any reprint can be obtained at the nominal cost listed below by circling the corresponding numbers on a reader service card, p. 175. Don't send money with card, we will bill you later. For multiple copies write Reader Service Dept. Quantity rates will be quoted on request.

505—The Basics of Optimum Response Relay Servos, 17 pp. Three part series summarizes all of the important design techniques that have been used to optimize the response of relay servos. The reprint describes the development of the optimum switching criteria, and outlines the progress that has been made in implementing this theory with hardware for second-order and higher-order systems. Extensive references provide a guide for further study. 50 cents.

504—System Characteristics of Modern Guidance Techniques, August 1960, 22 pp. In this special report five experts from three companies cover the system characteristics of inertial navigators, guidance radars, Doppler radar techniques, modern techniques in celestial navigation, and perceptive guidance systems. 65 cents.

503—How to Determine Stream Analyzer Dynamics, 8 pp. This package of two articles shows how analyzers can introduce dynamic errors, how to determine analyzer dynamics, and how to improve performance. The instrument used is a differential refractometer but techniques can be extrapolated to other types of analyzers. 40 cents.

502—Survey of Dynamic Display Techniques, 20 pp. The function of these newly developed techniques is to put up-to-date information in the hands of human operators of control systems when the information changes at a high rate. Both basic approaches and commercial hardware are discussed for cathode ray tube displays, optical systems, and miscellaneous devices ranging from TV pickup to matrix cells. 50 cents.

501—Six Transducers for Precision Position Measurement, May 1960, 6 pp. Explains operation and gives practical application hints for six precision position transducers: pin-and-pawl mechanism, magnetic bench-mark system, resolver-type transducer, electrostatic transducer, coded-disc devices, and diffraction gratings. 30 cents.

500—Ready Reference Data Files—I, II, III, 76 pp. The feature here is a
Continued on page 197

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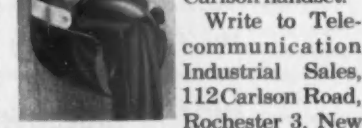


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No. 29: high-gain version of No. 28 handset.

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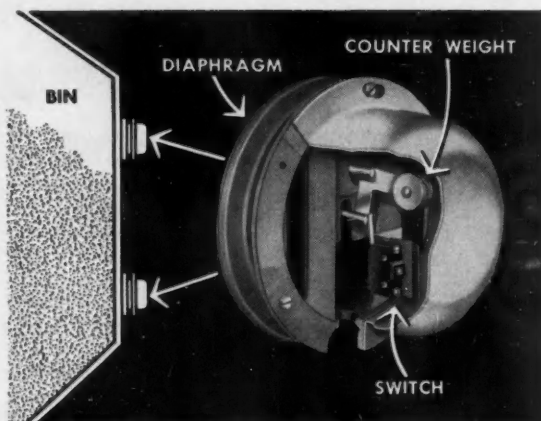
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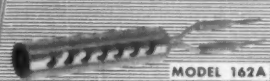
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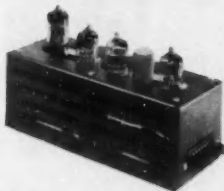
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OCTOBER 1960

REPRINTS cont'd

special rate for those who purchase all of the Data Files published in *CONTROL ENGINEERING* through April 1960. The 36 articles included in this package cover analysis, design, and application short-cuts for all phases of the control field. Everyone can use this timeless reference material. \$1.35.

499—Ready Reference Data Files—III, 28 pp. Includes the third dozen Data Files published in *CONTROL ENGINEERING*. Topics range from control of metal properties with eddy currents to electrically signaled valve actuators to stabilization of sampled data systems. 60 cents.

498—Ready Reference Data Files—II, 24 pp. Includes the second dozen data files published in *CONTROL ENGINEERING*. Topics covered range from analyzing hydraulic servos graphically to using silicon diodes as protective devices. 50 cents.

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496—How to Specify Instrument Accuracy, 8 pp. This basic reprint is aimed at helping the user and maker to develop clear and mutual agreement on allowable instrument errors. Discussions of uncertainties of zero, scale factor, and instantaneous slope aid in the intelligent specification of allowable errors and preferred test procedures. 40 cents.

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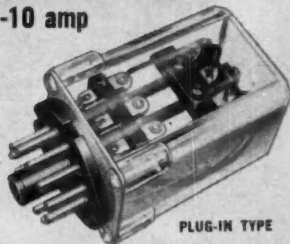
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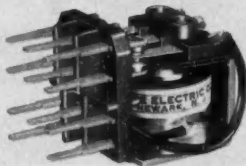
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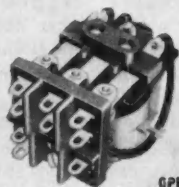
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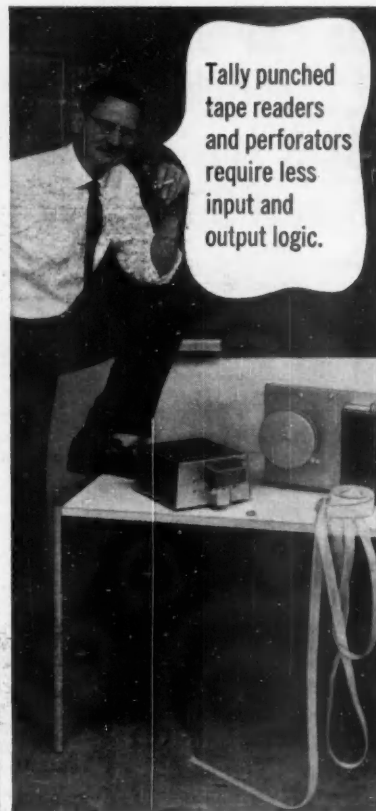
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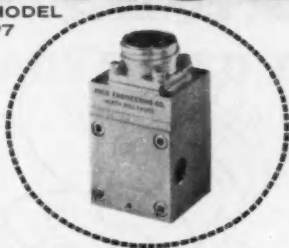
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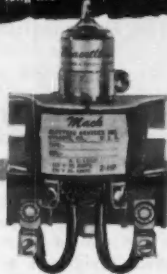
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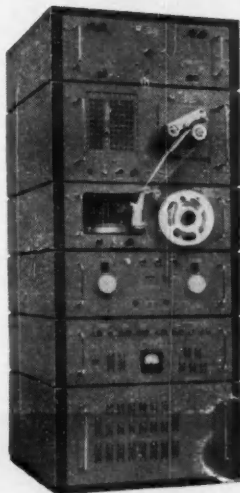
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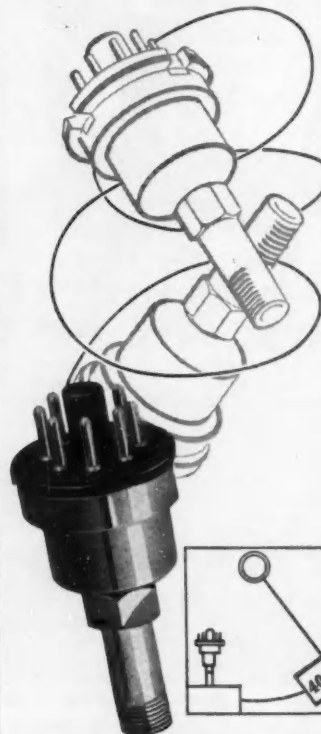
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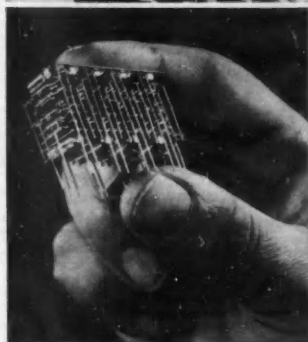
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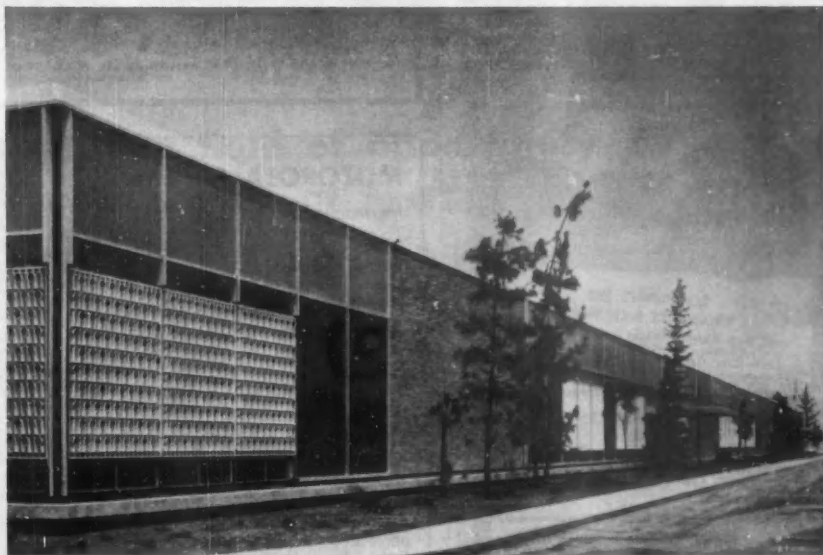
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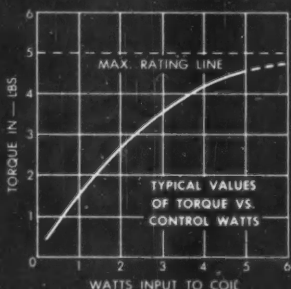
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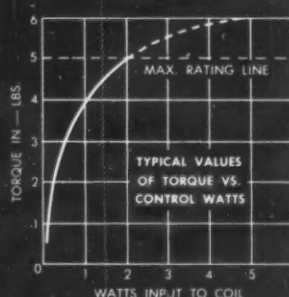
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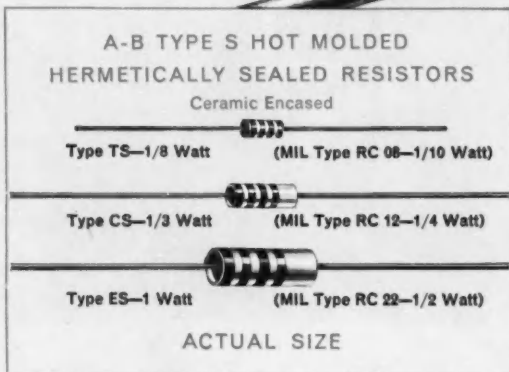
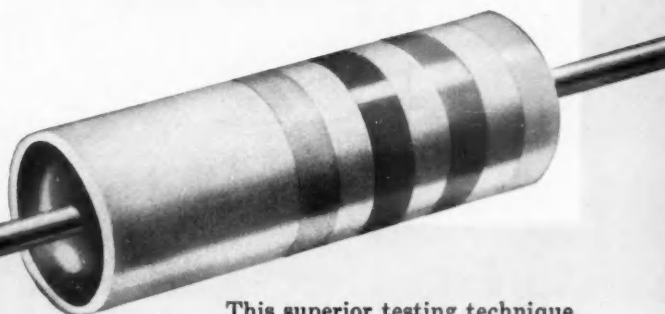
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